PROCEEDINGS
OF THE
ROYAL SOCIETY OF EDINBURGH.

VOL. XII. 1882–83. No. 113.

The Hundredth Session.

GENERAL STATUTORY MEETING.

Monday, 27th November 1882.

PROFESSOR **MACLAGAN**, Vice-President, in the Chair.

The following Council were elected:—

President.

THE RIGHT HON. LORD MONCREIFF.

Vice-Presidents.

Prof. DOUGLAS MACLAGAN, M.D.
Prof. H. C. FLEEMING JENKIN, F.R.S.
Rev. W. LINDSAY ALEXANDER, D.D.
J. H. BALFOUR, M.D., F.R.S.
THOMAS STEVENSON, M.In.C.E.
ROBERT GRAY, Esq.

General Secretary—Professor TAIT.

Secretaries to Ordinary Meetings.
Professor TURNER, F.R.S.
Professor CRUM BROWN, F.R.S.

Treasurer.—ADAM GILLIES SMITH, Esq., C.A.

Curator of Library and Museum—ALEXANDER BUCHAN, Esq., M.A.

Councillors.

Professor CHRYSTAL.
Sheriff FORBES IRVINE.
Professor A. DICKSON.
The Right Rev. Bishop COTTERILL.
Rev. Professor DUNS.
Dr RAMSAY TRAQUAIR.
JOHN MURRAY, Esq.
WILLIAM FERGUSON, Esq.
Professor COSSAR EWART.
Professor JAMES GEIKIE.
Rev. Dr W. ROBERTSON SMITH.
STAIR AGNEW, Esq.

By a Resolution of the Society (19th January 1880) the following Hon. Vice-Presidents, having filled the office of President, are also Members of the Council:—

HIS GRACE THE DUKE OF ARGYLL, K.T., D.C.L.
SIR WM. THOMSON, LL.D., D.C.L., F.R.S., Foreign Associate of Institute of France.

Monday, 4th December 1882.

THE RIGHT HON. LORD MONCREIFF, President, in the Chair.

The President gave a short historical sketch of the Society on the occasion of the commencement of its Hundredth Session. He said that, before the business commenced, he ought to call attention to a peculiarity of the present meeting, and to make one or two observations upon it. This was the hundredth session of the Royal Society. Most cordially did he congratulate the Society and its members on having arrived at that interesting period of its history. But it was right he should say that it would be a mistake to suppose that, although this was the hundredth session, they were absolutely centenarian. This was not the anniversary of the birth of the Royal Society. For some reason or other—he did not know how—the hundredth session began before the Society was absolutely a hundred years old. How it exactly came about he was not quite sure. The Royal Society's charter bore date March 1783; and he supposed, like other great institutions, they had a previous autumn session—and in that way, possibly, the difference was to be accounted for. But, in any view, it is a great occasion for meditation and observation, and there may come a time for such a word, but on the present occasion he had not the material sufficient to do anything like justice to a theme so large. Only in a few sentences would he go back to March 1783, and glance upon the long career which the Society had run. A long and distinguished course, he thought they might say, seeing it was to their distinguished predecessors they owed its glory and its present flourishing existence. There had been many speculations as to where the Royal Society came from, and its feeders had been examined and searched for with great assiduity. There was a Rankinian Club in Edinburgh towards the beginning of last century, and it was claimed as the foundation of the Royal Society. Then there was a Select Society, a debating club—somewhere about 1750—where Dr Robertson and the great men of those days practised the oratory which they afterwards used with such effect; and they had been told that that to a large extent was the origin of the Royal Society. He had looked into the Appendix to Dugald Stewart's *Life of Robertson*, and there he found a list of members of the Select Society—and it contained many, if not all, of the names of the great men who were in 1783 among its members. One distinctive thing he could gather from the notice was, that Adam Smith and David Hume were both members of it, and that neither one nor the other ever opened their lips in the Society during the time they were members of it. But he rather thought a third institution had more claim, and that was the Philosophical Society, founded by Colin Maclaurin, the great mathematician. Undoubtedly it did survive till the period when the Royal Society was formed. Colin Maclaurin, unfortunately for himself, was the engineer employed to defend Edinburgh at the time of the advance of the Pretender in 1745, and he had to leave Edinburgh. Observations had sometimes been made as if Maclaurin had made a somewhat precipitate retreat on that occasion, but the real fact was, he was the last man who left, for he found, after all the fortifications were complete, that there was nobody to man them, and no army to help in the defence. He was not the only man who had to retreat, for he rather thought the Court of Session also took that course, and before the Pretender arrived the Judges had departed to their country seats. Such was the parentage of the Royal Society. In 1783 these streams all seemed to meet, and this institution was the result. They had originally a literary side and a physical or mathematical side. At the first start they had 104 on the physical side and 114 members on the literary side. He was looking back to an address by his much valued and lamented friend Professor Forbes, which was delivered in 1862, and he would go over a few names given there as belonging to the physical side and to the literary side, and they would probably agree with him (there were many more who might go alongside of them) that it would be difficult to find in any part of Britain, or in any country out of Britain, an assemblage of persons more distinguished in their respective spheres. The physical side embraced Joseph Black, Clerk of Eldin, Lord Hailes, James Gregory, James Hutton, John Playfair, Dugald Stewart, Lord Bute, Lord Dundonald, Sir James Hall, James Watt, Dr Small (Dundee), and Patrick Wilson. And on the literary side there were the Lord President, Chief Baron, the Lord Advocate, John Home, David Hume, Henry Mackenzie, Alexander Tytler, the Duke of Buccleuch, Archibald Alison, Dr Beattie, Edmund Burke, Lord Morton, Lord Hopetoun, John Hunter, Thomas Reid, Young of Glasgow, and Mr Liston. That was a nucleus for a great Society; and certainly from that time forward it grew and prospered until the position of a Fellow of the Royal Society of Edinburgh became one of the highest distinction. Now, it appeared, they had lasted for one hundred years. Whether they all of them could come up to the mark of the great men whose names he had read he did not know. For one thing, we knew many things they did not know, although they possibly knew a great many that we did not know; but, looking back from 1783 till now, it was a wonderful retrospect in point of knowledge and invention and progress—owing, to a large extent, to the labours of the men whose names he had just mentioned. The literary side was presided over by Sir Thomas Miller of Barskimming, who held the office of Lord Justice-Clerk, the office the speaker had the honour to hold. He was a man of very great powers—a great lawyer, and a man of very strong literary tastes. But he did not know that the literary side had quite made the progress they might have looked for during that time. It did last for about twenty years in great vigour. He had the curiosity to see what the subjects were that were treated of. There were some very vigorous papers; and among them he found a dissertation by John Maclaurin, the son of the mathematician, the object of which was to prove that Troy was not taken by the Greeks after all, which he tried to prove with a wonderful amount of learning. Perhaps he might be excused if he suggested that possibly it would be an improvement if in this respect also they followed more closely in the footsteps of their predecessors. These observations he concluded by wishing the Royal Society all prosperity in the next hundred years.

The President read the following statement in regard to the number of the Fellows of the Society :—

I. Honorary Fellows—

Royal Personage—

His Royal Highness the Prince of Wales, . 1

British Subjects at November 1881.

John Couch Adams, LL.D., Cambridge; Sir George Biddell Airy, K.C.B., Greenwich; Thos. Andrews, M.D., Belfast; Arthur Cayley, LL.D., Cambridge; Chas. Darwin, M.A., F.R.S., Kent; John Anthony Froude, LL.D., London; Sir William Robert Grove, London; Thomas Henry Huxley, LL.D., D.C.L., London; James Prescott Joule, LL.D., D.C.L., Manchester; Richard Owen, C.B., M.D., London; Thomas Romney Robinson, D.D., D.C.L., LL.D., Armagh; General Sir Edward Sabine, K.C.B., London; Rev. George Salmon, D.D., LL.D., D.C.L., Dublin; Henry John Stephen Smith, LL.D., Oxford; Balfour Stewart, LL.D., Manchester; George Gabriel Stokes, LL.D., D.C.L., Cambridge; James Joseph Sylvester, LL.D., Baltimore; Alfred Tennyson, D.C.L., Isle of Wight. Total, 18

Of these Charles Darwin and Dr T. Romney Robinson died during the Session. Deduct, 2

Total Number of British Honorary Fellows at November 1882, ... 16

Foreign Honorary Fellows at November 1881.

Robert Wilhelm Bunsen, Heidelberg; Michel Eugène Chevreul, Paris; James D. Dana, Newhaven, U.S.; Alphonse De Caudolle, Geneva; Franz Cornelius Donders, Utrecht; Jean Baptiste Dumas, Paris; Carl Gegenbaur, Heidelberg; Asa Gray, Harvard, U.S.; Hermann Ludwig Ferdinand Helmholtz, Berlin; Jules Janssen, Paris; August Kekule, Bonn; Gustav Robert Kirchhoff, Berlin; Hermann Kolbe, Leipzig; Albert

Carry forward, 17

Brought forward, 17

Kolliker, Würzburg; Ernst Eduard Kummer, Berlin; Richard Lepsius, Berlin; Ferdinand de Lesseps, Paris; Rudolph Leuckart, Leipzig; Johann Benedict Listing, Göttingen; Joseph Liouville, Paris; Sven Lovén, Stockholm; Carl Ludwig, Leipzig; J. N. Madvig, Copenhagen; Henry Milne-Edwards, Paris; Theodore Mommsen, Berlin; Simon Newcomb, Washington; Louis Pasteur, Paris; Émile Plantamour, Geneva; Carl Theodor von Siebold, Munich; Johannes Japetus Smith Steenstrup, Copenhagen; Otto Wilhelm Struve, Pulkowa; Bernard Studer, Bern; Otto Torell, Lund; Rudolph Virchow, Berlin; Wilhelm Eduard Weber, Göttingen; Friedrich Wöhler, Göttingen.

Total number at November 1881, 36

Of these three died during the course of last Session,—Joseph Liouville, Émile Plantamour, and Friedrich Wöhler.

Deduct . . 3

Total Number at November 1882, . 33

Total Number of British and Foreign Honorary Fellows at November 1882, . 50

II. Ordinary Fellows—

The Ordinary Fellows of the Society at November 1881 were 408

Fellows since elected—Sir Peter Coats; Andrew Young, Esq.; D. B. Dott, Esq.; Dr James Clerk Rattray; Alexander Leslie, Esq.; John Sturgeon Mackay, Esq.; Dr Henry Barnes; James Sorley, Esq.; William Thomson, Esq.; Thomas Graham Young, Esq.; W. Dyce Cay, Esq.; J. A. Dixon, Esq.; Professor C. Michie Smith; D. H. Marshall, Esq.; Josiah Livingston, Esq.; Dr David Pryde; J. W. Inglis, Esq.; Frank W. Young, Esq.; T. R. Buchanan, Esq., M.P.; Dr George Wilson; Frank E. Beddard, Esq.; Andrew Jamieson, Esq.; J. A. Wenley, Esq. 23

Carry forward, 431

Brought forward, 431

Deceased during Session 1881–82 — David Anderson, Esq. of Moredun; Charles D. Bell, Esq.; Dr John Brown; Sir Robert Christison, Bart.; Sir John Rose Cormack; J. Anthony Dixon, Esq.; Sheriff Frederick Hallard; James Hay, Esq.; William King, Esq.; John M'Culloch, Esq.; Sir Daniel Macnee; Dr Charles Morehead; Dr John Muir; Richard Parnell, Esq.; Samuel Raleigh, Esq.; Dr William Robertson; John Scott Russell, Esq.; Professor Spence; Sir Wyville Thomson; James Walker, Esq.; Robert Wilson, Esq. Deduct . 21

Total Number of Ordinary Fellows at November 1882, . 410

Total Number of Honorary Fellows at November 1882, . 50

Total Number of Fellows of the Society at November 1882, 460

Obituary Notices were read of Charles Darwin, Émile Plantamour, Charles Davidson Bell, Dr William Robertson, Sir Daniel Macnee, David Anderson, John M'Culloch, Samuel Raleigh, and Professor James Spence, deceased Fellows of the Society.

The following Communications were read:—

1. Dr Guébhard's Electro-Chemical Method of Figuring Equipotential Lines. By Rev. Dr W. R. Smith.

2. Message from the Nautical Almanac Office, in reference to the Transit of Venus, Dec. 6, 1882. Communicated by the Astronomer-Royal.

Royal Observatory, Edinburgh,
4th December 1882.

The following despatch has just been received from Mr J. R. Hind, Superintendent of the Nautical Almanac, London:—

"First external contact at 1 h. 48 m. 24 sec., mean time at Edinburgh; the place of it being at 147° N. to E. for direct image.

"First internal contact will be 21 minutes later."

The above notification indicates that the phenomena will occur 5 minutes and a few seconds later than the times printed four years ago, under difficulties, in the Nautical Almanac.

Observers should therefore be warned and prepared accordingly: viz., for 2 h. 1 m. 7 sec. in place of 1 h. 55 m. 57 sec. P.M. of Greenwich mean time as per Time-Ball and Time-Gun here in Edinburgh.

The place of first external contact will also be 2 degrees on the sun's limb nearer to its south pole, but on the east side, as before.

C. Piazzi Smyth,
Astronomer-Royal for Scotland.

To General Secretary,
Royal Society, Edinburgh.

BUSINESS.

The following Candidates were balloted for and declared duly elected Fellows of the Society:—Dr R. H. Gunning; Alexander Bruce, M.A., M.B.; Dr Charles D. F. Phillips.

Monday, 18th December 1882.

ROBERT GRAY, Esq., Vice-President, in the Chair.

The following Communications were read:—

1. On the Laws of Motion. Part I. By Professor Tait.

(*Abstract.*)

The substance of part at least of this paper was given in 1876 as an evening lecture to the British Association at its Glasgow meeting.

While engaged in writing the article "Mechanics" for the *Ency. Brit.*, I had to consider carefully what basis to adopt, and decided that the time had not yet come in which (at least in a semi-popular article) Newton's laws of motion could be modified. The article was therefore based entirely on these laws, with a mere hint towards the end that in all probability they would soon require essential modification. It is well, however, that the question of modification should now be considered; and this should be done, not in a popular essay but, before a scientific society.

The one objection to which, in modern times, that wonderfully complete and compact system is liable, is that it is expressly founded on the conception of what is now called "force" as an agent which "compels" a change of the state of rest or motion of a body. This is part of the first law, and the second law is merely a definite statement of the amount of change produced by a given force.

(Next comes a digression as to what was Newton's expression for what we now mean by the word force, when it is used in the correct signification above.)

There can be no doubt that the proper use of the term *force* in modern science is that which is implied in the statement—Force is whatever changes a body's state of rest or motion. This is part of the first law of motion. Thus we see that force is the English equivalent of Newton's term *vis impressa.* But it is also manifest that, on many occasions, *but only where his meaning admitted of no doubt*, Newton omitted the word *impressa* and used *vis* alone, in the proper sense of force. In other cases he omitted the word *impressa*, as being implied in some other adjective such as *centripeta*, *gravitans*, &c., which he employed to qualify the word *vis.* Thus (Lemma X.) he says :—*Spatia, quæ corpus urgente quâcunque vi finitâ describit*, &c. It is needless to multiply examples. But that this is the true state of the case is made absolutely certain by the following:—

Definitio IV. Vis impressa est actio in corpus exercita, ad mutandum ejus statum vel quiescendi vel movendi uniformiter in directum.

Contrast this with the various senses in which the word *vis* is used in the comment which immediately follows, viz.:—

Constitit haec vis in actione solâ, neque post actionem permanet in corpore. Perseverat enim corpus in statu omni novo per solam vim inertiæ. Est autem vis impressa diversarum originum, ut ex ictu, ex pressione, ex vi centripetâ.

These passages are translated by Motte as below :—

"*Definition IV. An impressed force is an action exerted upon a body, in order to change its state, either of rest, or of moving uniformly forward in a right line.*"

"This force consists in the action only, and remains no longer in the body when the action is over. For a body maintains every new state it acquires, by its *vis inertiæ* only. Impressed forces are of different origins; as from percussion, from pressure, from centripetal force."

The difficulty which Motte here makes for himself, and which he escapes from only by leaving part of the passage in the original Latin, is introduced solely by his use of the word *force* as the equivalent of the Latin *vis.*

If we paraphrase the passage as follows, with attention to Newton's obvious meaning, this difficulty disappears, or rather does not occur:—

"This kind of vis consists in," &c. For the "body continues . . . . by the vis of inertia," &c. However, we may quote two other passages of Newton bearing definitely on this point.

Definitio III. Materiæ vis insita est potentia resistendi, quâ corpus unumquodque, quantum in se est, perseverat in statu suo vel quiescendi vel movendi uniformiter in directum.

It is perfectly clear that, in this passage, the phrase *vis insita* is one idea, not two, and that *vis* cannot here be translated by *force.* Yet Motte has

"The *vis insita*, or innate force of matter, is," &c.

Definitio V. Vis centripeta est, quâ corpora versus punctum aliquod, tanquam ad centrum, undique trahuntur, impelluntur, vel utcumque tendunt.

It is obvious that the qualifying term *centripeta* here includes the idea suggested by *impressa,* defining in fact the direction of the *vis,* and therefore implying that its origin is outside the body.

After what has just been said, no farther comment need be added to show the absurdity of the terms *accelerating force, innate force, impressed force,* &c. All of these have arisen simply from mistranslation. Vis, by itself, is often used for force; but *vis acceleratrix, vis impressa, vis insita,* and other phrases of the kind, must be taken as wholes; and, in them, *vis* does not mean *force.*

The absurdity of translating the word *vis* by *force* comes out still more clearly when we think of the term *vis viva,* or *living force* as it is sometimes called; a name for kinetic energy, which depends on the unit of length in a different way from force. It must be looked upon as one of the most extraordinary instances of Newton's clearness of insight that, at a time when the very terminology of science was only as it were shaping itself, he laid down with such wonderful precision a system absolutely self-consistent.

From the passages just quoted, taken in conjunction with the second law of motion, we see that (as above stated) in Newton's view—

Force is whatever causes (but not, *or tends to cause*) *a change in a body's state of rest or motion.*

Newton gives no sanction to the so-called *statical* ideas of force. Every force, in his view, produces its effect. The effects may be such as to balance or compensate one another; but there is no balancing of forces.

(Next comes a discussion as to the objectivity or subjectivity of force. An abstract of this is given in §§ 288–296 of the article above referred to, and therefore need not be reproduced here.)

But, just as there can be no doubt that force has no objective existence, so there can be no doubt that the introduction of this conception enabled Newton to put his *Axiomata* in their exceedingly simple form. And there would be, even now, no really valid objection to Newton's system (with all its exquisite simplicity and convenience) could we only substitute for the words "force" and "action," &c., in the statement of his laws, words which (like rate or gradient, &c.) do not imply objectivity or causation in the idea expressed. It is not easy to see how such words could be introduced; but assuredly they will be required if Newton's system is to be maintained. The word stress might, even yet, be introduced for this purpose; though, like force, it has come to be regarded as something objective. Were this possible, we might avoid the necessity for any very serious change in the *form* of Newton's system. I intend, on another occasion, to consider this question. How complete Newton's statement is, is most easily seen by considering the so-called "additions" which have been made to it.

The second and third laws, together with the scholium to the latter, expressly include the whole system of "effective forces," &c. for which D'Alembert even now receives in many quarters such extraordinarily exaggerated credit. The "reversed effective force" on a particle revolving uniformly in a circle is nothing but an old friend—"centrifugal force." And even this phantom is still of use, *in skilled hands*, in forming the equations for certain cases of motion.

The chief arguments for and against a modern modification of the laws of motion are therefore as follows—where we must remember that they refer exclusively to the elementary teaching of the subject, and have no application to the case of those who have sufficient knowledge to enable them to avoid the possible dangers of Newton's method:—

I. FOR. Is it wise to teach a student by means of the conception of force, and then as it were to kick down the scaffolding by telling him there is no such thing?

II. AGAINST. Is it wise to give up the use of a system, due to such an altogether exceptional genius as that of Newton, and which amply suffices for all practical purposes, merely because it owes part of its simplicity and compactness to the introduction of a conception which, though strongly impressed on us by our muscular sense, corresponds to nothing objective?

Everyone must answer these questions for himself, and his answer will probably be determined quite as much by his notions of the usefulness of the study of natural philosophy as by his own idiosyncrasies of thought. To some men physics is an abomination, to others it is something too trivial for the human intellect to waste its energies on. With these we do not reason. To others again all its principles are subjects of intuitive perception. *They* could have foreseen the nature of the physical world, and they *know* that it could not have been otherwise than they suppose it to be. Many minds find delight in the contemplation of the three kinds of lever; others in the ingeniously disguised assumptions in Duchayla's "proof" of the parallelogram of forces; some, perhaps, even in the wonderful pages of *Vis Inertiæ Victa!* The case of these men is only not more hopeless than that of the former classes because it is impossible that it could be so.

But those who desire that their scientific code should be, as far as possible, representative of our real knowledge of objective things, would undoubtedly prefer to that of Newton a system in which there is not an attempt, however successful, to gain simplicity by the introduction of subjective impressions and the corresponding conceptions.

In the present paper simplicity of *principle*, only, is sought for; and the mathematical methods employed are those which appeared (independent altogether of the question of their fitness for a beginner) the shortest and most direct. A second part will be devoted to simplicity of *method* for elementary teaching.

(1) So far as our modern knowledge goes there are but two objective things in the physical world—matter and energy. Energy cannot exist except as associated with matter, and it can be perceived and measured by us only when it is being transferred, by a "dynamical transaction," from one portion of matter to another. In such transferences it is often "transformed"; but no process has ever been devised or observed by which the quantity, either of matter or energy, has been altered.

(2) Hence the true bases of our subject, so far as we yet know, are—

1. Conservation of matter.
2. Conservation of energy.
3. That property (those properties ?) of matter, in virtue of which it is the necessary vehicle, or as the case may be, the storehouse, of energy.

(3) The third of these alone presents any difficulty. So long as energy is obviously kinetic, this property is merely our old friend *inertia*. But the mutual potential energy of two gravitating masses, two electrified bodies, two currents, or two magnets, is certainly associated (at least in part, and in some as yet unknown way) with matter, of a kind not yet subjected to chemical scrutiny, which occupies the region in which these masses, &c., are situated. And, even when the potential energy obviously depends on the strain of a portion of ordinary matter, as in compressed air, a bent spring, a deformed elastic solid, &c., we can, even now, only describe it as due to "molecular action," depending on mechanism of a kind as yet unknown to us, though, in some cases, at least partially guessed at.

(4) The necessity for the explicit assumption of the third principle, and a hint at least of the limits within which it must be extended, appear when we consider the very simplest case of motion, viz., that of a lone particle moving in a region in which its potential energy is the same at every point. For the conservation of energy tells us merely that its *speed* is unaltered. We know, however, that this is only part of the truth: the *velocity* is constant. It will be seen later that this has most important dynamical consequences in various directions.

(The remarkable discussion of this point by Clerk-Maxwell is then referred to, in which it is virtually shown that, were things otherwise, it would be possible for a human mind to have knowledge of *absolute* position and of *absolute* velocity.)

(5) But Maxwell's reasoning is easily seen to apply equally to any component of the velocity. Hence, when we come to the case in which the potential energy depends on the position, the only change in the particle's motion at any instant is a change of the speed in the normal to the equipotential surface on which the particle is at that instant situated. The conservation of energy assigns the amount of this change, and thus the motion is completely determined. In fact, if x be perpendicular to the equipotential surface, the equation

$$\tfrac{1}{2}m(\dot{x}^2+\dot{y}^2+\dot{z}^2)+V=\text{const},$$

gives

$$m\ddot{x}=-\frac{dV}{dx},$$

for $\dot{y}$ and $\dot{z}$ are independent of x. Generally, in the more expressive language of quaternions,

$$m\ddot{\rho}=-\nabla V.$$

In fact, this problem is precisely the same as was that of the motion of a luminous corpuscle in a non-homogeneous medium, the speed of passing through any point of the medium being assigned.

(6) It is next shown that the above inertia-condition (that the velocity parallel to the equipotential surface is the same for two successive elements of the path) at once leads to a "stationary" value of the sum of the quantities vds for each two successive elements, and therefore for any finite arc, of the path. This is, for a single particle, the *Principle of Least Action*, which is thus seen to be a direct consequence of inertia.

(It is then shown that the results above can be easily extended to a particle which has two degrees of freedom only.)

But it is necessary to remember that, in these cases, we take a partial view of the circumstances; for a lone particle cannot strictly be said to have potential energy, nor can we conceive of a constraint which does not depend upon matter other than that which is constrained. Hence the true statement of such cases requires further investigation.

(7) To pass to the case of a system of free particles we require

some quasi-kinematical preliminaries. These are summed up in the following self-evident proposition :—If with each particle of a system we asssciate two vectors, *e.g.*, Θ_1, Φ_1, with the mass m_1, &c., we have

$$\Sigma m\Theta\Phi = \Sigma(m) \,.\, \Theta_0\Phi_0 + \Sigma m\theta\phi,$$

where

$$\Theta = \Theta_0 + \theta,$$
$$\Phi = \Phi_0 + \phi,$$

and

$$\Sigma m\Theta = \Sigma(m) \,.\, \Theta_0$$
$$\Sigma m\Phi = \Sigma(m) \,.\, \Phi_0,$$

so that Θ_0 and Φ_0 are the values of Θ and Φ for the whole mass collected at its centre of inertia; and θ, ϕ, those of the separate particles relative to that centre.

(8) Thus, if $\Theta = \mathrm{P} = \mathrm{P}_0 + \rho$ be the vector of m, $\Phi = \Theta = \dot{\mathrm{P}} = \dot{\mathrm{P}}_0 + \dot{\rho}$, its velocity, we have

$$\Sigma m\mathrm{P}\dot{\mathrm{P}} = \Sigma(m) \,.\, \mathrm{P}_0\dot{\mathrm{P}}_0 + \Sigma m\rho\dot{\rho}$$

the scalar of which is, in a differentiated form, a well-known property of the centre of inertia. The vector part shows that the sum of the moments of momentum about any axis is equal to that of the whole mass collected at its centre of inertia, together with those of the several particles about a parallel axis through the centre of inertia.

If

$$\Theta = \Phi = \dot{\mathrm{P}},$$

we have

$$\Sigma m\dot{\mathrm{P}}^2 = \Sigma(m) \,.\, \dot{\mathrm{P}}_0^2 + \Sigma m\dot{\rho}^2,$$

i.e., the kinetic energy, referred to any point, is equal to that of the mass collected at its centre of inertia, together with that of the separate particles relative to the centre of inertia.

If we integrate this expression, multiplied by dt, between any limits, we obtain a similar theorem with regard to the action of the system.

Such theorems may be multiplied indefinitely.

(9) From those just given, however, if we take them along with 3 above, we see at once that, provided the particles of the system be all free, while the energy of each is purely kinetic and independent alike of the configuration of the system and of its position in space,

1. The centre of inertia has constant velocity.

2. The vector moment of momentum about it is constant.

3. So is that of the system relative to any uniformly moving point.

4. $\Sigma\int mvds$ is obviously a minimum.

(10) The result of (7) points to an independence between two parts of the motion of a system, *i.e.*, that relative to the centre of inertia, and that of the whole mass supposed concentrated at the centre of inertia. Maxwell's reasoning is applicable directly to the latter, if the system be self-contained, *i.e.*, if it do not receive energy from, or part with it to, external bodies. Hence we may extend the axiom 3 to the centre of inertia of any such self-contained system, and, as will presently be shown, also to the motion of the system relative to its centre of inertia. This, though not *formally* identical with Newton's Lex III., leads, as we shall see, to exactly the same consequences.

(11) If, for a moment, we confine our attention to a free system consisting of two particles only, we have

$$m_1\dot{\rho}_1 + m_2\dot{\rho}_2 = (m_1 + m_2)\alpha,$$

or

$$m_1\ddot{\rho}_1 + m_2\ddot{\rho}_2 = 0 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

This must be consistent with the conservation of energy, which gives

$$\tfrac{1}{2}(m_1\dot{\rho}_1^2 + m_2\dot{\rho}_2^2) = f(\mathrm{T}(\rho_1 - \rho_2)) \quad . \quad . \quad . \quad . \quad . \quad (2)$$

since the potential energy must depend (so far as *position* goes) on the distance between the particles only. Comparing (1) and (2) we see that we may treat (2) by partial differentiation, so far as the coordinates of m_1 and m_2 are separately concerned. For we thus obtain

$$m_1\ddot{\rho}_1 = \nabla_{\rho_1} . f = f . \mathrm{U}(\rho_1 - \rho_2)$$
$$m_2\ddot{\rho}_2 = \nabla_{\rho_2} . f = -f' . \mathrm{U}(\rho_1 - \rho_2).$$

Each of these, again, is separately consistent with the equation in § (5) for a lone particle. Hence, again, the integral $\int(m_1v_1ds_1 + m_2v_2ds_2)$ has a stationary value.

Hence also, whatever be the origin, provided its velocity be constant,

$$\Sigma m\mathrm{V}\rho\ddot{\rho} = 0.$$

Thus, even when there is a transformation of the energy of the system, the results of § 9 still hold good. And it is to be observed that if one of the masses, say m_2, is enormously greater than the other, the equation

$$m_1\ddot{\rho}_1 + m_2\ddot{\rho}_2 = 0$$

shows that $\ddot{\rho}_2$ is excessively small, and the visible change of motion is confined to the smaller mass. Carrying this to the limit, we have the case of motion about a (so-called) "fixed centre." In such a case it is clear that though the *momenta* of the two masses relative to their centre of inertia are equal and opposite, the kinetic energy of the greater mass vanishes in comparison with that of the smaller.

These results are then extended to any self-contained system of free particles, and the principle of *Varying Action* follows at once. It is thus seen to be a general expression of the three propositions of § 2 above.

(12) So far as we have yet gone, nothing has been said as to *how* the mutual potential energy of two particles depends on their distance apart. If we suppose it to be enormously increased by a very small increase of distance, we have practically the case of two particles connected by an inextensible string—as a chain-shot. But from this point of view such cases, like those of connection by an extensible string, fall under the previous categories.

The case of impact of two particles falls under the same rules, so far as motion of the centre of inertia, and moment of momentum about that centre, are concerned. The conservation of energy, in such cases, requires the consideration of the energy spent in permanently disfiguring the impinging bodies, setting them into internal vibration, or heating them. But the first and third of these, at least, are beyond the scope of abstract dynamics.

(13) The same may be said of constraint by a curve or surface, and of loss of energy by friction or resistance of a medium. Thus a constraining curve or surface must be looked upon (like all physical bodies) as deformable, but, if necessary, such that a very small deformation corresponds to a very great expenditure of energy.

(14) To deal with communications of energy from bodies outside the system, all we need do is to *include them in the system.* Treat as before the whole system thus increased, and then consider only

the motion of the original parts of the system. This method applies with perfect generality whether the external masses be themselves free, constrained, or resisted.

(15) Another method of applying the same principles is then given. Starting from the *definition* $dA = \Sigma m S\dot{\rho} d\rho$, the kinematical properties of A are developed. Then, by the help of § 2, these are exhibited in their physical translations.

(16) The paper concludes with a brief comparison of the fundamental principles of the science as they have been introduced by Newton, Lagrange, Hamilton, Peirce, Kirchhoff, and Clerk-Maxwell, respectively; and also as they appear in the unique Vortex-system of Thomson.

2. On Illegitimacy in Scotland. By Mr Geo. Seton, M.A. Oxon.

In the year 1860, at the meeting of the Social Science Association in Glasgow, I read a paper on "The *Causes* of Illegitimacy in Scotland," which was published shortly afterwards; and eleven years later (1871), at the meeting of the British Association in Edinburgh, I read another paper on "The Illegitimacy of Banffshire," which was privately printed. On the present occasion I intend to confine my observations to the *facts* exhibited by the Registrar-General's returns.

For a good many years a perceptible improvement has been going on in England in the matter of illegitimacy; and I am glad to be able to add that in Scotland also we have evidence of a gradual, and nearly as satisfactory, diminution in the number of illegitimate births. During the two decades, ending 1870 and 1880 respectively, the decrease in England was rather more, and in Scotland rather less, than 1 per cent.

PERCENTAGE OF ILLEGITIMACY.

	1861–70.	1871–80.	Decrease.
ENGLAND, ...	6·1	5·0	1·1
SCOTLAND, ...	9·7	8·8	0·9

From the Forty-second Annual Report of the English Registrar-

General it appears that, during the thirty-four years ending 1879, the proportion of illegitimate children to every 100 births gradually fell from 6·7 to 4·7 per cent., or exactly 2 per cent., as shown in the following table:—

ENGLAND.

CHILDREN BORN OUT OF WEDLOCK TO 100 BIRTHS.

1846–50,	6·7
1851–55,	6·6
1856–60,	6·5
1861–65,	6·4
1866–70,	5·8
1871–75,	5·2
1876–79,	4·7

As in Scotland, the rates have always greatly varied in different counties. While the average for the whole of England during the ten years ending 1879 was 5·1 per cent., that for Cumberland was as high as 8·9—little more, however, than half the percentage for Banffshire, and only a fraction above the average for Scotland. In the extra-metropolitan portion of Middlesex the percentage was as low as 3·6. With regard to illegitimacy, England may be roughly divided into three zones:—(1) a southern zone with the rate below the average; (2) a midland zone with the rate somewhat above the average; and (3) a northern zone with an excessively high rate. Perhaps, therefore, our English neighbours will feel disposed to suggest that the proximity of the northern counties to Scotland may have something to do with their high rate of illegitimacy.* Both the English and Scottish returns show that in the great centres of population the percentage of illegitimacy is much smaller than in the rural districts. It must, however, be constantly borne in mind that a comparison of the numbers of illegitimate births in town and country districts respectively is not in itself sufficient to afford any indication of the true state of morality. Every statist is aware that the unrestrained passions which in rural districts result in illegitimate births are in large towns diverted into the channel of barren prostitution. The English Registrar-General remarks that, "it is probable that a considerable portion of illegitimate children are the offspring of country girls who have gone into domestic service in towns, and have there been seduced; and such girls will often return to the country for their confinement, and thus increase the country rate of illegitimacy by the addition of births which from their origin should duly be reckoned as belonging to the towns." On the other hand, however, it is quite as likely that a good many mothers of illegitimate children conceived in rural districts resort to private lodgings or maternity hospitals in large towns for the purpose of being confined.

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* It has been frequently alleged that under the Scottish system of registration the illegitimate births are more accurately recorded than in England; and that if the respective returns were equally trustworthy, the difference in the ratio of illegitimacy on the two sides of the Tweed would not be so great as it has hitherto appeared. I am disposed to think that there is some truth in the assertion. Roughly speaking, the percentage of illegitimacy in England and Scotland, as indicated by the returns, is at present about 5 and 9 respectively. Probably 7 and 9 per cent. is nearer the actual fact. The object of this paper, however, is not to compare the two countries, but to show the vast differences in the percentage of illegitimacy which present themselves in the various counties of Scotland.

In Scotland, during the two decades ending 1870 and 1880 respectively, there had been a diminution in the rate of illegitimacy to the extent of nearly 1 per cent., viz., 8·8 instead of 9·7. If a wavy line be drawn from Portskerry, about twelve miles west of Thurso, to Fort-George, and thence, by the eastern boundaries of Inverness, Argyll, Stirling, Lanark, and Ayr, to the mouth of Loch Ryan, it will be found that all the counties to the west of the line present a percentage of illegitimacy below the ratio for the whole of Scotland; while two-thirds of the counties to the east of the line present a percentage above that ratio—the majority of the others yielding a percentage closely bordering on the national rate. There were thus ten counties on the west of the line in question below the national ratio; while of the twenty-one counties on the east of the line, fourteen ranged from 9·0 (Nairn) to 16·6 (Banff), and the remaining seven from 7·3 (Fife) to 8·7 (Selkirk). One of these seven (Edinburgh) contains a large city, while three others (Fife, Clackmannan, and Selkirk) embrace towns of considerable size, thereby probably accounting, by the barren prostitution of large centres, for the comparatively small number of illegitimate births. The insular counties (Orkney and Shetland) were considerably below the national average—having respectively 6·0 and 4·8 per cent.

In 1881 the population of the Western area amounted to 1,859,000, and of the Eastern area to 1,814,000—a difference of only 45,000. By far the larger portion of the Western area is occupied by an almost purely Celtic population; while the inhabitants of the Eastern area, with the exception of the county of Perth, are chiefly Scandinavian or Teutonic.

In three of the eleven counties constituting the northern division of Scotland,—viz., Nairn, Aberdeen, and Kincardine,—and in all the counties south of Banffshire, with the exception of four,—amounting in all to twenty,—the decrease in the rate of illegitimacy ranged from 0·5 per cent. in the case of Roxburgh, to 1·9 per cent. in the case of Clackmannan. On the other hand, in eight of the eleven northern counties, and also in Argyll, Linlithgow, Dumfries, and Kirkcudbright—in all twelve counties—there had been an increase in the rate, ranging from 0·1 per cent. in Ross and Cromarty, and Dumfries, to no less than 2·2 per cent. in Caithness. In both decades Banffshire retained the discreditable distinction of being at the top of the list, showing the slight increase of 0·4 per cent. (16·6 instead of 16·2)—in other words, one illegitimate child in every six births, or nearly double the percentage for the whole of Scotland. One county (Wigtown) was stationary at 16·1 per cent. The two blackest spots have always been three adjoining counties in the north (Elgin, Banff, and Aberdeen), and three adjoining southern counties (Wigtown, Kirkcudbright, and Dumfries), the collective percentage of the two groups being almost identical.

In the case of rather more than one-fourth of the whole illegitimate births the paternity was acknowledged at registration; in a good many instances the paternity was subsequently found by decree of court and recorded in terms of the statute; while about 3 per cent. of the children were legitimated by the subsequent marriage of their parents.*

* During the four years ending 1861, of the 7517 births registered in Banffshire, 1189 were illegitimate. In the case of 389 of these children—or nearly a third of the whole—the paternity was acknowledged at registration; in 64 instances the paternity was subsequently found by decree of court and recorded in terms of the statute; and in 28 cases the children were legitimated *per subsequens matrimonium,* such alteration of statu being also duly registered. In a few instances the judicial findings relate to children whose paternity was acknowledged at registration, from which it would appear that, notwithstanding the reputed father's adhibition of his signature to the register, the mother is occasionally induced to raise an action against him. Of course the paternity of some more of the "fatherless"

PERCENTAGE OF ILLEGITIMACY IN SCOTLAND AND ITS COUNTIES.

	1861–70.	1871–80.	Increase or Decrease.
SCOTLAND,	9·7	8·8	−0·9
COUNTIES.			
NORTHERN.			
Shetland,	4·2	4·8	+0·6
Orkney,	5·0	6·0	+1·0
Caithness,	8·7	10·9	+2·2
Sutherland,	5·8	6·9	+1·1
NORTH-WESTERN.			
Ross and Cromarty,	4·5	4·6	+0·1
Inverness,	8·0	8·3	+0·3
NORTH-EASTERN.			
Nairn,	10·7	9·0	−1·7
Elgin,	14·0	15·7	+1·7
Banff,	16·2	16·6	+0·4
Aberdeen,	15·2	14·3	−0·9
Kincardine,	14·4	13·3	−1·1
EAST MIDLAND.			
Forfar,	11·9	10·5	−1·4
Perth,	11·0	9·8	−1·2
Fife,	8·1	7·3	−0·8
Kinross,	11·2	10·3	−0·9
Clackmannan,	9·9	8·0	−1·9
WEST MIDLAND.			
Stirling,	8·4	7·0	−1·4
Dumbarton,	7·4	5·8	−1·6
Argyll,	7·3	7·8	+0·5
Bute,	8·0	7·4	−0·6
SOUTH-WESTERN.			
Renfrew,	7·4	6·2	−1·2
Ayr,	9·1	8·0	−1·1
Lanark,	8·4	7·3	−1·1
SOUTH-EASTERN.			
Linlithgow,	7·9	8·3	+0·4
Edinburgh,	9·1	7·8	−1·3
Haddington,	9·5	8·2	−1·3
Berwick,	10·9	10·3	−0·6
Peebles,	9·9	8·5	−1·4
Selkirk,	9·3	8·7	−0·6
SOUTHERN.			
Roxburgh,	11·5	11·0	−0·5
Dumfries,	14·9	15·0	+0·1
Kirkcudbright,	15·0	15·2	+0·2
Wigtown,	16·1	16·1	0·0

In his report relative to the year 1880, Mr Daniel Stewart, the intelligent examiner of registers in the southern district of Scotland, gives some very startling information regarding the illegitimacy of the counties of Roxburgh, Dumfries, Kirkcudbright, and Wigtown. In no fewer than 33 parishes in these four counties, the illegitimate births amounted to 20 per cent. and upwards—a certain small parish in Roxburghshire exhibiting the enormous ratio of 36·3 per cent.! He refers to the large number of cases in which *sisters* give birth to illegitimate children, and to the numerous instances of the same woman being the mother of several children. Thus, in each of twelve specified parishes, two sisters registered illegitimate births during 1880. These 24 women had given birth to 41 children. In the case of twelve of them it was the first child, while the remaining twelve had collectively produced 29 children. In each of three parishes in three of the counties in question, *three* sisters have had nine children among them, while a trio in a certain Berwickshire parish have had at least ten. In nine parishes, mothers recorded their fifth, and in five parishes, their sixth child; most of them being either domestic servants or engaged in some kind of agricultural labour. In two cases, in the counties of Kirkcudbright and Selkirk respectively, a charwoman and a dressmaker each recorded their seventh child. To only a small extent is the illegitimacy of the counties in question to be accounted for by the prevalence of concubinage.

The result of Mr Stewart's inquiries seems to point irresistibly to "a wide-spread low moral tone among domestic and farm servants in rural parishes," and mainly to that cause he is disposed to attribute the large proportion of illegitimate births constantly occurring in the southern counties. Many registrars have told him that "language of the most immoral kind is quite common among out-workers and other women engaged in farm work; and when they have once fallen they appear to lose all sense of shame and self-respect."

Note.—Mr Stewart's report for 1881 (which has been received since this paper was written) furnishes further evidence of the pre-

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majority may yet be judicially established, and other cases of legitimation by the subsequent marriage of the parents may also take place; but no very material addition is likely to be made to the figures specified.

valence of illegitimacy, especially in the four counties already referred to. The following table exhibits some very startling facts:—

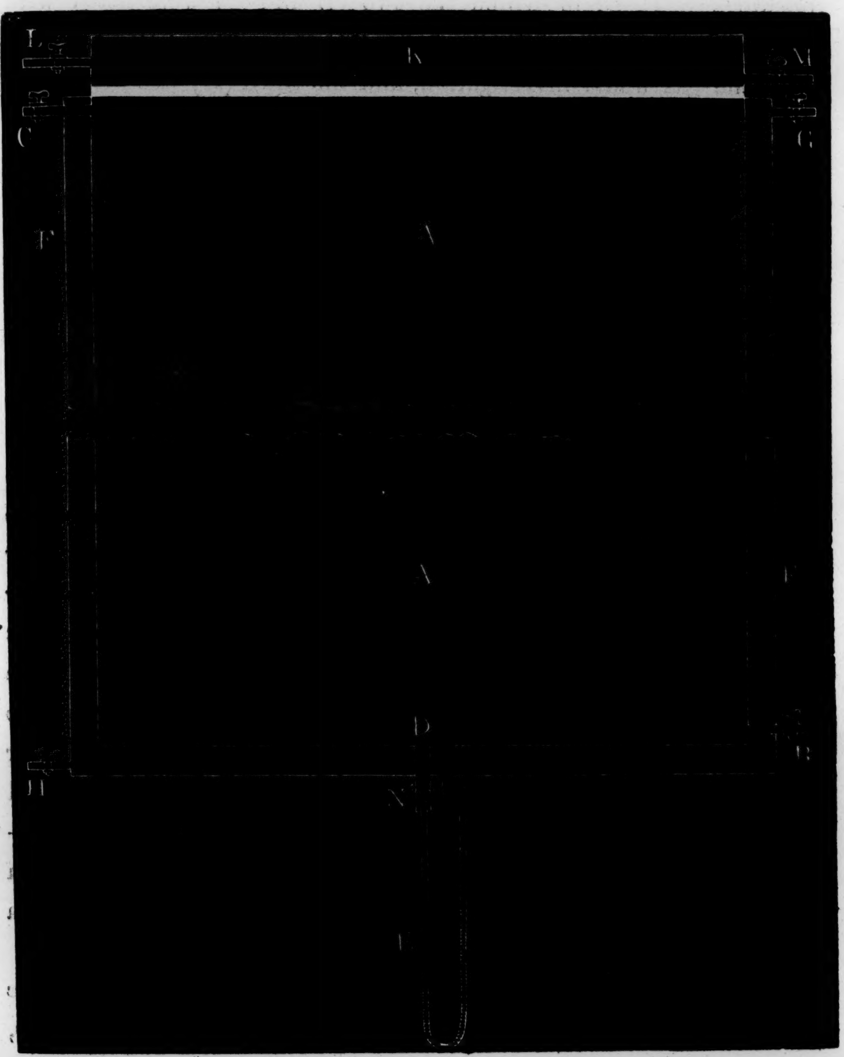
SOUTHERN DISTRICT—1881.

County.	Number of Illegitimate Births.	Percentage of Illegitimates.	Number of Child of Mother.									Total Number of Women Confined before.	Total Number of Children among them.
			2nd.	3rd.	4th.	5th.	6th.	7th.	8th.	9th.	10th.		
Roxburgh,	170	10·4	11	9	4	...	1	...	...	...	...	25	71
Dumfries,	349	14·8	28	11	1	5	1	...	1	...	...	47	132
Kirkcudbright,	157	12·4	9	6	2	...	1	2	...	...	...	20	64
Wigtown,	182	15·3	9	10	2	2	1	...	1	...	1	26	90
	858	...	57	36	9	7	4	2	2	...	1	118	357

In a small Dumfriesshire parish a domestic servant, who recorded her third (or fourth) illegitimate child, has three sisters, each of whom has given birth to three bastard children—"who make a trade of the offence" (in the words of the local registrar), "as they afterwards go out as nurses." In another parish in the same county, the percentage of illegitimacy had reached the alarming ratio of 40·7 per cent.! In the county of Wigtown there was not a single parish without illegitimate births, and only in two parishes was the rate below the national average. In the other 15 parishes, the percentage ranges from 9·6 to 24·1. Numerous instances of *hereditary* illegitimacy occur in the southern counties—many women (themselves illegitimate) and their daughters recording bastards in the same register.

3. On the Absorption of Low Radiant Heat by Gaseous Bodies. By Professor MacGregor.

The following pages contain an account of experiments made by myself and Mr T. Lindsay, at the request of Professor Tait, to determine the absorption of damp air containing a known quantity of water vapour, by finding in what proportions dry air and olefiant gas must be mixed in order that the absorption of the mixture may be the same as that of the damp air. The experiments were made according to the method described by Professor Tait in a letter read by Sir William Thomson at the Southampton meeting of the British Association (see *Nature*, vol. xxvi. p. 639, 1882). They consist of two series—the first, a series of rough experiments made, first, to determine whether or not the method would work, and, secondly, to find the dimensions of the apparatus which would give the best result; the second, a series of more careful experiments made when the method was found to give satisfactory results.



The apparatus which we used for the preliminary experiments is shown in diagrammatic section in the figure. It consisted of a cylindrical gas reservoir (A, A) of tinned iron, about 4 feet in length and 4·5 inches in diameter. This reservoir may be called the absorber. It was placed with its axis vertical. It had three openings B, C, D, of which the two (B and C) were fitted with metal tubes and stopcocks, and were used for filling the reservoir with the gas under investigation, and the third (D) was fitted with a metal tube holding the manometer E. The curved surface and the bottom of the absorber were surrounded by another cylindrical vessel F, F, also of tinned iron, whose sides were everywhere about 0·5 inch from the sides of the absorber. This outer casing had two openings (G, H) fitted with tubes and stopcocks, the one at the bottom, the other at the top. By their means the space between A and F could be kept full of running water. On the upper end of the absorber was a flat cylindrical box (K) about 1 inch in depth. The upper end of the cylinder formed the bottom of the box. This box, which may be called the radiator, was also provided with two stopcocks and tubes L, M, placed as in the diagram, by means of which it could be filled with either water or steam. For this purpose an india-rubber tube from M dipped under water in a sink, while L could be put in communication by means of a three-way tube with either a boiler or the water supply. The absorber was thus completely surrounded by a jacket divided into two compartments, one of which was the radiator. The manometer E consisted of a bent tube of about 1^{mm} bore. It was provided with a stopcock N, was fitted in the tube D by means of an india-rubber stopper, and contained dilute sulphuric acid of known density. The levels of the liquid were read off by the aid of a card, with a divided scale, which was attached to the tube.

The following is a description of our mode of observation. The absorber was first filled with the gas under investigation. Thus, to fill with dry air, B was attached to a series of drying tubes (sulphuric acid and chloride of calcium) and C to the suction pump, and a current was kept up until the dry air had displaced the damp air which at first filled A. To fill with moist air, the drying tubes were replaced by wetting tubes. To fill with olefiant gas, C was left open, and the gas driven in from the generator at B until the air initially filling A had been displaced. Meantime water had been kept running through both compartments of the jacket. The water from the laboratory reservoir was found to be practically invariable in temperature during the course of any one experiment. When the absorber had been filled, and the water had been running through the jacket for some time, the stopcocks B and C were closed and D opened. The water was then kept running through the jacket until the gas in the absorber had attained a practically constant temperature, until the liquid in the manometer therefore indicated a practically constant pressure. The barometer and manometer were then read, and the temperature of the water jacket noted. Then L was put in communication with the boiler, and the water in the radiator was displaced by steam, after which the variation of the manometer with time was noted until it had again reached a constant state, when the barometer was again read. If the readings of the barometer before and after any set of observations were not the same, it was supposed to have varied uniformly with time in calculating pressures. In all cases the difference was very slight, the sets of observations lasting only from 20 to 30 minutes. From the readings of the barometer and manometer the pressures were easily calculated.

No precautions were taken specially to exclude dust, so that, when water was present in the gas operated on, it was not necessarily all in the state of vapour.

The following are details of some of the experiments made. The unit employed in the measurement of pressure is that due to a millimetre of the dilute acid solution used in the manometer. Its density was 1·1038. Zero of time is the moment at which communication was broken between the radiator K and the water supply, and established between the radiator and the boiler. Shortly after that the upper end of the absorber begins to rise in temperature, and the pressure of the gas contained in it to increase. When the steam issues freely from the radiator, it may be supposed to have very nearly reached a constant temperature.

I. *Dry Air.*—Air had been drawn from the drying tubes through the absorber for 2 hours. The following table shows the pressures after given intervals of time :—

Time.		Pressure.
m.	s.	
0	0	9316·9
0	20	9319·7
0	30	9325·7
0	37	9335·7
0	45	Steam issuing freely.
0	56	9337·7
1	17	9339·7
1	43	9340·7
2	15	9341·7
3	0	9342·7
3	45	9343·7
4	15	9344·7
5	30	9346·7
6	20	9347·7
7	30	9348·7
9	33	9350·7
10	52	9351·7
12	32	9352·7
13	47	9353·9
15	17	9354·7
18	17	9356·7
20	52	9357·7

II. *Damp Air.*—Air had been drawn through the absorber for 15 minutes, after having passed through a Woulfe's bottle of water.

Time.		Pressure.
m.	s.	
0	0	9311·2
0	15	9311·7
0	20	9319·7
0	26	9325·7
0	31	9330·7
0	37	Steam issuing freely.
0	54	9331·2
1	8	9331·7
1	55	9332·2
3	6	9332·7
5	10	9334·7
6	0	9335·7
9	15	9337·7
10	30	9338·7
14	5	9340·7

III. *Damp Air.*—The air had for 2 hours been drawn through the absorber, after passing through a Woulfe's bottle containing water.

Time.		Pressure.
m.	s.	
0	0	9314·6
0	15	9316·6
0	22	9328·6
0	27	9333·6
0	35	9335·6
0	36	Steam issuing freely.
0	45	9336·6
1	15	9336·6
2	25	9336·6
3	55	9337·1
4	25	9337·6
5	25	9338·1
12	0	9338·1

IV. *Damp Air.*—The same air as in No. III.

Time.		Pressure.	Time.		Pressure.
m.	s.		m.	s.	
0	0	9314·1	2	30	9333·6
0	27	9323·6	3	45	9334·1
0	32	9328·6	4	20	9334·6
0	40	9332·6	5	30	9335·6
0	41	Steam issuing freely.	7	45	9337·1
			8	45	9337·6
1	6	9333·1	13	45	9338·1
1	35	9333·5	15	0	9338·1

V. *Dry Air.*—The air had been drawn through the absorber and drying tubes for 3½ hours.

Time.		Pressure.	Time.		Pressure.
m.	s.		m.	s.	
0	0	9334·9	2	0	9356·4
0	24	9336·4	2	15	9357·4
0	32	9338·4	2	35	9358·4
0	40	9341·4	3	25	9359·4
0	45	9343·4	4	45	9362·4
0	50	9346·4	5	15	9363·4
0	57	9348·4	6	20	9364·4
1	5	9351·4	7	45	9368·4
1	6	Steam issuing freely.	9	35	9370·4
			11	12	9372·4
1	20	9354·4	12	54	9373·4
1	30	9355·4	16	0	9375·4

VI. *Dry Air.*—The same air as in No. V.

Time.		Pressure.	Time.		Pressure.
m.	s.		m.	s.	
0	0	9326·4	2	30	9350·4
0	20	9336·4	3	0	9351·4
0	25	9342·4	3	25	9352·4
0	30	9346·4	3	45	9353·4
0	36	9348·4	5	0	9356·4
0	36	Steam issuing freely.	5	25	9357·4
			6	20	9358·4
0	46	9349·4	8	40	9362·4
1	5	29349·6	12	15	9364·4

VII. *Dry Air.*—Air was again drawn through the drying tubes and absorber for one hour.

Time.		Pressure.	Time.		Pressure.
m.	s.		m.	s.	
0	0	9334·9	1	4	9358·9
0	18	9343·4	1	46	9359·4
0	23	9348·4	2	20	9361·4
0	28	9353·4	3	25	9363·4
0	34	9356·4	4	45	9367·4
0	34	Steam issuing freely.	6	30	9372·4
			8	20	9375·4
0	43	9358·4			

VIII. *Damp Air.*—The air was drawn through the wetting tubes and the absorber for 2·75 hours.

Time.		Pressure.	Time.		Pressure.
m.	s.		m.	s.	
0	0	9333·8	3	0	9354·8
0	20	9343·8	4	15	9356·8
0	29	9350·8	5	10	9357·8
0	34	9351·8	5	55	9358·8
0	34	Steam issuing freely.	7	55	9361·3
			8	35	9361·8
0	45	9352·6	11	0	9362·8
1	28	9353·3	13	25	9363·8
2	25	9353·8	19	0	9364·8

IX. *Damp Air.*—The same air as in No. VIII.

Time.		Pressure.	Time.		Pressure.
m.	s.		m.	s.	
0	0	9323·4	2	5	9342·7
0	9	9323·9	2	50	9342·9
0	18	9325·9	3	35	9343·9
0	23	9329·9	4	25	9345·9
0	29	9335·9	6	40	9349·9
0	35	9339·9	7	13	9350·9
0	40	9341·9	9	20	9351·9
0	40	Steam issuing freely.	10	40	9351·9
			13	0	9351·9
0	56	9342·7			

X. *Olefiant Gas.*—The absorber was now carefully dried, dry air being drawn through it, while steam was driven through both compartments of the jackets. Then the jacket was filled with water, and the air in the reservoir displaced by dry olefiant gas, made according to the method recommended by Roscoe and Schorlemmer in their *Treatise on Chemistry.* The olefiant gas was driven through drying apparatus into the absorber, the tube C being open to the atmosphere, until the gas issuing from C burned with a white flame.

Time.		Pressure.
m.	s.	
0	0	9232·3
0	18	9233·3
0	24	9236·3
0	28	9241·3
0	33	9245·3
0	38	9248·3
0	44	9250·3
0	44	Steam issuing freely.
0	50	9251·3
1	0	9252·3
1	10	9253·3
1	18	9254·3
1	30	9255·3
1	45	9256·3
2	4	9257·3
2	22	9258·3
2	50	9259·3
3	50	9261·3
4	45	9264·3
5	45	9266·3
8	0	9271·3
10	0	9274·3
13	7	9277·3
17	0	9277·3

XI. *Dry Air.*—The olefiant gas was next displaced by dry air.

Time.		Pressure.
m.	s.	
0	0	9087·9
0	10	9088·8
0	15	9093·8
0	20·5	9099·0
0	27	9105·0
0	36	9107·2
0	48·5	9108·3
0	49	Steam issuing freely.
1	0	9110·1
1	11	9110·8
1	25	9112·0
1	57	9114·0
2	40	9117·3
3	38	9120·3
4	56	9124·6
6	45	9130·4
8	23	9139·0
10	0	9143·6
11	54	9150·6
14	41	9158·4
16	34	9165·4
20	10	9174·9
23	0	9181·7
26	15	9190·0
29	53	9197·6
31	58	9202·6
35	40	9209·2

XII. *Dry Air, containing a small quantity of Olefiant Gas.*—A very small quantity of dry olefiant gas was driven into the absorber which contained the dry air already used for Experiment XI.

Time.		Pressure.
m.	s.	
0	0	9256·6
0	8	9257·6
0	15	9258·6
0	20	9259·6
0	24	9261·6
0	29	9266·6
0	34	9268·6
0	40	9272·6
0	41	Steam issuing freely.
0	44	9273·6
0	53	9274·1
1	5	9274·6
1	51	9275·6
3	44	9276·6
5	45	9278·6
6	32	9279·6
7	54	9281·8
8	51	9282·6
10	37	9284·6
17	46	9286·6
23	18	9288·6

If the above experiments be represented by curves, with intervals of time as abscissæ and increments of pressure as ordinates, it will be seen (1) that the curves have all, except in the case of Experiment XI., the same general form; (2) that the curves for dry air tend, after different intervals of time, to the same value of ordinate, except in the curiously anomalous case of Experiment XI.; (3) that the curves for air containing different quantities of water vapour occupy in all cases a lower position on the diagram than those for dry air; (4) that the curve for olefiant gas is above that for dry air; and (5) that the curve for dry air, containing a small quantity of olefiant gas, is in the same region of the diagram as those for moist air. We thought it worth while, therefore, to try to find how much olefiant gas must be added to dry air to give a curve coinciding with that of air containing a known quantity of vapour.

It seemed advisable, however, to increase the radiating surface relatively to the surface of the absorber. The apparatus which we used for subsequent experiments therefore differed from that already described in two respects. The diameter of the cylindrical absorber was 18 inches, and the plate separating the radiator K from the absorber A was of copper, and $\frac{3}{16}$ in. thick. It was made thick to prevent, as much as possible, its giving way under the pressure to which it was subjected, when the radiator was in communication with the boiler or the water supply. It was made of copper, that its conductivity might be as great as possible.

The curved sides and bottom of the absorber were made as before of the stoutest commercial tinned iron. We thought it unnecessary to have it made more rigid, as the pressure of the water in the jacket was constant during each experiment. The copper plate bent under the pressure of the water and the steam, however, more than we anticipated, and the differences in the amount of the bending caused perceptible changes of form in the sides. The pressures given below are subject therefore to sudden slight variations, which depend upon sudden changes of volume of the absorber, not upon absorption. Hence the numbers given below cannot be taken as exact results. It will be noticed in the experiments made with this apparatus, that after the steam is turned on in the radiator, previously filled with running water, the pressure at first diminishes, and only after a certain time increases. This is not due to absorption, but to the fact that the water pressure in the laboratory was slightly greater than the boiler pressure which we used. When, therefore, the water pressure was taken off the sides of the radiator K, and the steam pressure was put on, the copper plate became less bent, and the reservoir therefore became suddenly larger, the pressure consequently falling. As might be expected, in the case of an apparatus not sufficiently rigid, the first experiments made with it were much more unsatisfactory than the last. The apparatus took gradually the set determined by the pressures employed. If the measurements given in the tables below are plotted, the resulting curves will be found far smoother in the case of the later than in that of the earlier experiments. For more exact experiments a more rigid apparatus should be employed.

For the following experiments a new manometer was used. It was made from a carefully selected tube of practically uniform bore.

The mode of procedure in the experiments with the new reservoir was practically the same as that described above. Tests were applied more frequently to find if the reservoir was air-tight, and to find if the drying tubes were efficient. Their efficiency was tested by weighing at intervals the last of the series.

XIII. *Air saturated with Water Vapour at* 13°·2 *C.*—The absorber being full of air, a small quantity of water was introduced by the opening D, and poured over the bottom. The absorber was then left standing for an hour. The temperature of the water in the jackets was 13°·2 C.

Time. m.	Time. s.	Pressure.
0	0	9023·8
0	27	9019·8
0	45	9018·8
1	13	9018·8
1	20	9019·8
1	36	9020·3
1	45	9020·8
2	4	9021·8
2	26	9022·8
2	46	9023·8
3	0	9024·8
3	15	9025·8
3	35	9027·8
3	37	9028·8
3	51	9029·8
4	7	9031·8
4	25	9033·8
4	36	9034·8
4	55	9036·8
5	5	9038·8
5	15	9039·8
5	53	9044·8
6	40	9049·8
6	55	9051·8
7	24	9054·8
7	42	9056·8
8	30	9059·8
9	5	9062·8
9	40	9064·8
10	35	9067·9
11	5	9074·9
11	40	9076·9
12	23	9080·9
13	2	9089·9
14	20	9094·9
15	20	9099·9
16	0	Steam issuing freely.
17	20	9109·9
18	18	9111·9
19	10	9112·9
19	30	9113·9
20	36	9114·2
21	6	9124·0
21	38	9125·0
22	30	9125·0
23	50	9125·0
25	25	9126·0

XIV. *Air saturated with Water Vapour at* 13° *C.*—The water and air in the absorber as in Experiment XIII. Temperature of the water jacket was 13° C.

Time. m.	Time. s.	Pressure.
0	0	9017·8
0	12	9016·8
0	20	9014·8
1	25	9015·8
1	37	9017·8
2	0	9018·8
2	17	9019·8
2	35	9020·8

Time.		Pressure.
m.	s.	
3	2	9022·8
3	20	9024·8
3	41	9027·8
4	8	9030·8
4	24	9032·8
4	40	9034·8
5	16	9038·8
6	6	9044·8
6	27	9047·8
6	50	9050·8
7	5	9052·8
7	28	9055·8
7	55	9057·8
8	50	9062·8
9	15	9064·8
10	0	9067·8
11	1	9072·8
11	42	9077·8
12	15	9082·8
13	0	9097·8
13	35	9100·8
14	10	9102·8
14	50	Steam issuing freely.
15	20	9107·8
16	10	9109·8
16	55	9112·8
19	40	9122·8
21	16	9123·8
22	50	9124·8

XV. *Dry Air.*—The absorber was dried by keeping both compartments of the jacket full of steam, and drawing dry air through the absorber until a U-tube of carefully dried calcium chloride placed between C and the suction-pump showed no change of weight in the course of an hour. Both compartments of the jacket were then kept full of running water, of temperature 12°·2 C., until the pressure of the air in the absorber had become constant, when as usual the radiator was put in communication with the boiler.

Time.		Pressure.
m.	s.	
0	0	9088·3
0	19	9087·3
0	28	9086·3
0	45	9085·3
1	10	9086·3
1	22	9087·3
1	47	9088·3
2	25	9090·3
2	53	9092·3
3	40	9095·3
4	0	9097·3
5	0	9102·3
5	45	9107·3
6	30	9112·3
7	0	9115·3
7	0	9117·3
7	50	9122·3
8	7	9127·3
8	50	9133·2
9	15	Steam issuing freely.
9	25	9137·3
10	0	9142·3
11	5	9147·3
16	0	9148·3
18	15	9151·3
23	0	9152·3
24	55	9154·3
28	0	9154·3

XVI. *Dry Air.*—The same air as in the last experiment, both compartments of the jacket having been again filled with water until the pressure had become constant.

Time.		Pressure.	Time.		Pressure.
m.	s.		m.	s.	
0	0	9085·3	5	30	9107·3
0	14	9084·3	6	20	9113·3
0	20	9083·3	6	47	9117·3
0	26	9082·3	7	25	9122·3
0	36	9081·3	8	0	9127·3
0	53	9080·3	8	0	Steam issuing freely.
1	5	9081·3			
1	14	9082·3	8	31	9132·3
1	40	9084·3	9	16	9137·3
1	55	9085·3	11	10	9140·3
2	9	9087·3	13	2	9141·3
2	50	9092·3	15	50	9142·3
3	37	9097·3	21	35	9142·5
4	35	9102·3	24	0	9142·5

XVII. *Mixture of Air and Olefiant Gas, containing* 1·1 *per cent. by volume of Olefiant Gas.*—The absorber being full of the dry air of last experiment, both compartments of the jacket were filled with running water of temperature 12° C. When the pressure had become constant, and had the value 9154·1, dry olefiant gas was driven into the absorber at B (C being kept closed) until the pressure had risen to 9256·8. Of the gas which the absorber contained, therefore 1·1 per cent. by volume was olefiant gas. The olefiant gas was prepared in the same manner as before, from rectified spirit and pure sulphuric acid.

Time.		Pressure.	Time.		Pressure.
m.	s.		m.	s.	
0	0	9173·8	1	25	9174·3
0	11	9173·2	1	38	9176·3
0	24	9172·2	1	47	9178·3
0	30	9171·2	2	4	9181·3
0	45	9170·2	2	21	9184·3
0	55	9171·2	2	30	9186·3
1	7	9172·2	2	38	9189·4

Time. m.	Time. s.	Pressure.	Time. m.	Time. s.	Pressure.
2	47	9191·4	6	30	9251·8
3	2	9194·4	6	50	9256·8
3	10	9196·4	7	0	Steam issuing freely.
3	19	9198·4	7	20	9266·9
2	35	9201·4	7	33	9271·9
4	10	9206·4	7	45	9276·9
4	30	9211·5	8	10	9282·0
4	53	9216·5	8	23	9287·0
5	0	9221·6	9	5	9292·0
5	13	9226·6	10	12	9297·1
5	29	9231·6	11	40	9298·1
5	45	9236·6	13	12	9299·1
6	5	9241·7			
6	17	9246·7			

XVIII. *Mixture of Air and Olefiant Gas, containing* 1·1 *per cent. by volume of Olefiant Gas.*—The absorber contained the same gas as before. Both compartments of the jacket had again been kept filled with running water at 12° C. until the pressure had become constant.

Time. m.	Time. s.	Pressure.	Time. m.	Time. s.	Pressure.
0	0	9102·8	6	18	9181·3
0	45	9104·8	6	31	9186·3
1	15	9105·8	6	50	9191·4
1	27	9107·8	7	7	9196·4
1	45	9110·8	7	33	9201·4
2	12	9115·9	8	0	Steam issuing freely.
2	35	9120·9	8	12	9211·5
3	0	9125·9	8	24	9216·5
3	18	9131·0	8	51	9221·6
3	40	9136·0	9	25	9226·6
3	57	9141·0	9	50	9231·6
4	17	9146·1	11	35	9233·6
4	40	9151·1	14	10	9235·7
4	55	9156·1	16	20	9236·7
5	15	9161·1	17	17	9239·7
5	32	9166·2	21	5	9240·7
5	48	9171·2	24	0	9241·7
6	4	9176·2			

XIX. *Mixture of Air and Olefiant Gas, containing* ·06 *per cent. by volume of Olefiant Gas.*—The mixture of dry air and olefiant gas used in Experiment XVIII. was driven out of the absorber by a current of dry air, which was drawn through the absorber for about twenty hours. When both compartments of the jacket had been filled with cold water, and B and C closed, the pressure took the constant value 9289·2. Dry olefiant gas was then driven into the absorber until the pressure took the constant value 9295·4. The gas which filled the absorber contained therefore ·05996 or about ·06 per cent. by volume of olefiant gas. The temperature of the gas at starting was 12°·9 C.

Time.		Pressure.
m.	s.	
0	0	9299·6
0	22	9298·7
0	48	9298·7
1	10	9298·5
1	30	9299·9
1	43	9301·0
2	0	9303·1
2	16	9306·1
2	28	9308·2
2	55	9313·3
3	20	9318·4
3	45	9323·5
4	13	9328·7
4	35	9333·8
4	57	9338·8
5	15	9344·0
5	40	9349·1
5	55	9354·2
6	5	Steam issuing freely.
6	20	9359·4
6	37	9364·5
7	0	9369·6
7	32	9371·6
7	47	9375·8
8	27	9377·1
10	35	9378·3
12	32	9379·8
14	10	9381·2
18	10	9383·0
20	54	9383·4

XX. *Mixture of Air and Olefiant Gas, containing* ·06 *per cent. by volume of Olefiant Gas.*—The absorber contained the gas used in Experiment XIX. Both compartments of the jacket having been filled with water at 12°·8 C., and the pressure having taken a constant value, the steam was turned on in the radiator.

Time.		Pressure.
m.	s.	
0	0	9296·1
0	16	9295·3
0	24	9294·3
0	30	9293·3

Time.		Pressnre.
m.	s.	
0	54	9292·3
1	15	9293·3
1	30	9295·3
1	40	9296·3
2	14	9301·4
2	37	9306·4
3	8	9311·4
3	32	9316·4
4	0	9321·4
4	15	9326·5
4	36	9331·5
4	55	9336·6
5	15	9341·6
5	35	9346·6
5	55	9351·7
6	15	9356·7
6	35	9361·7
6	50	Steam issuing freely.
7	4	9367·8
7	23	9371·8
7	48	9376·8
8	27	9381·9
9	13	9383·9

The bursting of the steam tube brought this experiment to an end.

XXI. *Mixture of Air and Olefiant Gas, containing* ·06 *per cent. by volume of Olefiant Gas.*—The same gas as that used in Experiment XIX. and XX. The absorber had again been completely surrounded by water at 12°·85 C., and the pressure had become constant.

Time.		Pressure.
m.	s.	
0	0	9303·9
0	5	9302·9
0	23	9301·9
0	30	9299·9
0	47	9298·9
1	7	9299·9
1	30	9302·9
2	10	9308·0
2	42	9313·0
3	12	9318·0
3	45	9323·0
4	7	9328·1
4	30	9333·1
4	55	9338·1
5	13	9343·2
5	32	9348·2
5	52	9353·2
6	13	9358·3
6	33	9363·3
6	55	9368·3
7	0	Steam issuing freely.
7	15	9373·4
7	35	9378·4
8	0	9383·4
8	30	9388·5
9	50	9391·5
11	3	9392·5
12	32	9393·5
15	33	9394·5
19	30	9395·5
22	25	9396·0

XXII. *Mixture of Air and Olefiant Gas, containing* 0·2 *per cent. by volume of Olefiant Gas.*—The absorber, containing the same gas as in the Experiments XIX., XX., and XXI., was surrounded by water at 12°·8 C., and the pressure when constant was found to be 9305·6. Dry olefiant gas was then driven in until the pressure had taken the constant value 9318·3. The mixture therefore contained ·19969 or about ·2 per cent by volume of olefiant gas.

Time.		Pressure.
m.	s.	
0	0	9318·3
0	19	9317·7
0	29	9315·7
0	41	9314·7
0	57	9315·7
1	7	9316·7
1	31	9319·8
2	14	9324·8
2	45	9329·8
3	12	9334·9
3	36	9339·9
4	1	9344·9
4	28	9350·0
4	50	9355·0
5	12	9360·0
5	34	9365·1
5	55	9370·1
6	12	9375·1
6	30	9380·2
6	52	9385·2
7	10	9390·2
7	30	9395·3
7	50	9400·3
8	0	Steam issuing freely.
8	16	9405·3
8	45	9410·4
9	15	9412·4
10	2	9415·4
10	45	9416·4
14	51	9418·4
17	0	9419·4
21	15	9419·4

XXIII. *Mixture of Air and Olefiant Gas, containing* 0·2 *per cent. by volume of Olefiant Gas.*—The absorber, containing the same mixture as in Experiment XXII., was surrounded by water at 12°·8 C., till the pressure had assumed a constant value. Then as usual the water was turned off from K, and the steam turned on.

Time.		Pressure.
m.	s.	
0	0	9323·1
0	13	9322·1
0	27	9321·1
0	33	9320·0
0	46	9319·0
0	58	9320·1
1	5	9321·2
1	23	9323·2
1	44	9326·2
2	15	9331·3

Time. m.	Time. s.	Pressure.
2	41	9336·3
3	10	9341·4
3	35	9346·4
3	55	9351·5
4	16	9356·5
4	37	9361·6
4	57	9366·7
5	16	9371·8
5	45	9376·8
6	0	9381·9
6	13	9386·9
6	30	9391·9
6	47	9397·0
7	8	9402·1
7	15	Steam issuing freely.
7	25	9407·1
7	48	9412·2
8	33	9417·3
10	20	9419·4
12	45	9420·6
18	0	9421·6
20	0	9421·8

XXIV. *Dry Air.*—The mixture of air and olefiant gas contained in the absorber in Experiment XXIII. was displaced by a current of dry air of about 47 c.c. per second (as determined by experiment), which was drawn through the apparatus for seven hours. At the end of that time (as determined by calculation) only about ·2 × ·0005 or ·0001 per cent. of the gas contained in the absorber would be olefiant gas.[1] A set of observations was made with this practically pure air, the temperature of the water jacket being 12°·9 C.

Time. m.	Time. s.	Pressure.
0	0	9375·2
0	51	9374·2
1	18	9377·3
1	46	9380·3
2	0	9382·3
2	30	9387·3
3	13	9392·4
3	43	9397·4
4	13	9402·4
4	40	9407·5
5	15	9312·5
5	45	9417·5
6	20	9422·6
7	0	Steam issuing freely.
7	3	9427·6
7	47	9432·6
9	15	9435·6
10	15	9436·6
14	0	9437·7
22	0	9438·2

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[1] If v is the volume of air entering in unit time, w the percentage of olefiant gas present after t units of time, w_0 the percentage present at beginning, and V the volume of the reservoir,

$$w = w_0 e^{-\frac{v}{V}t}.$$

XXV. *Mixture of Air and Olefiant Gas, containing* ·032 *per cent. by volume of Olefiant Gas.*—The absorber, filled with the dry air of Experiment XXIV., was surrounded by water at 12°·6 C. When a constant pressure of 9338·5 had been attained, dry olefiant gas was driven into the vessel, raising the pressure to 9341·5. Hence the mixture contained ·032 per cent. by volume of olefiant gas.

Time.		Pressure.	Time.		Pressure.
m.	s.		m.	s.	
0	0	9340·9	5	30	9374·0
0	17	9339·9	6	13	9379·1
0	26	9338·9	6	52	9384·1
0	54	9336·9	7	15	Steam issuing freely.
1	14	9338·9	7	50	9394·1
2	0	9343·9	8	24	9399·1
2	38	9349·0	10	15	9404·1
3	10	9354·0	12	20	9405·0
3	41	9359·0	13	50	9406·0
4	13	9364·0	19	10	9406·4
4	53	9369·0			

XXVI.—*Damp Air, containing* 1·3 *per cent. by volume of Water Vapour.*—A current of the damp air of the laboratory was drawn through the absorber, which contained initially the gas in Experiment XXV., until, as determined by calculation, it contained a quantity of olefiant gas so small as to be negligible. The quantity of water vapour present in the damp air, with which the reservoir was then filled, was found by determining the dew-point. The room in which the experiments were carried out was large, and there was a slow passage of air through it. The dew-point was determined by observation of wet and dry bulb thermometers. The temperatures they indicated were respectively 15° and 12°·8 C. The barometric pressure (reduced to 0° C.) was 759·83 mm. The pressure of the water vapour was therefore 9·71 mm., and the damp air contained consequently 1·278 (or about 1·3) per cent. by volume of water vapour.

Time.		Pressure.	Time.		Pressure.
m.	s.		m.	s.	
0	0	9331·6	0	55	9329·1
0	25	9330·1	1	17	9330·0

Time. m.	Time. s.	Pressure.	Time. m.	Time. s.	Pressure.
1	35	9333·0	7	0	Steam issuing freely.
2	8	9338·0			
2	35	9343·0	7	9	9400·1
3	0	9348·0	7	24	9405·1
3	27	9354·1	7	42	9408·1
3	48	9358·1	8	8	9413·1
4	8	9363·0	8	30	9418·2
4	25	9368·0	9	42	9423·1
4	47	9373·1	11	42	9425·0
5	30	9378·1	13	45	9425·9
5	58	9383·1	14	35	9426·8
6	25	9390·1	21	0	9427·1
6	42	9392·1			

XXVII. *Air saturated with Water Vapour at* 12°·4 *C.*—Water had been put inside the absorber twelve hours before the experiment, and some of it was still lying unevaporated in the vessel. The air therefore was saturated. The temperature of the water jacket when the reservoir was completely surrounded by water, and the pressure was constant, was 12°·4 C. Hence the pressure of water vapour was about 10·68 mm. The barometric pressure (reduced to 0° C.) was 757·65 mm.

Time. m.	Time. s.	Pressure.	Time. m.	Time. s.	Pressure.
0	0	9306·4	6	14	9353·0
0	33	9304·4	6	56	9358·1
1	8	9304·4	7	27	9363·2
1	30	9307·4	8	2	9368·3
2	8	9312·5	8	25	9373·3
2	43	9317·5	8	30	Steam issuing freely.
3	14	9322·6			
3	42	9327·6	8	51	9378·4
4	10	9332·8	10	0	9383·5
4	35	9337·8	12	45	9387·6
4	59	9342·9	16	30	9388·9
5	20	9348·0	19	30	9390·1

If these experiments be represented by curves after the same manner as the former ones, the following results become apparent: —(1) The manometric effect is very much greater with the new than with the old apparatus. (2) The curves for any one gas, or mixture of gases, do not coincide with one another. Thus corresponding ordinates of the two curves for air containing 1·1 per cent. of olefiant gas differ by about 4 or 5 per cent., or, as it may be put, one curve is 4 or 5 per cent. lower than the other. Of the two curves for air with 0·2 per cent. of olefiant gas, one is 2 to 4 per cent. lower than the other. Of the two for air with 0·06 per cent. of the same gas, one is from 6 to 10 per cent. lower than the other. Hence the apparatus used was incapable of giving perfectly accurate results. As we have pointed out above, the reservoir was not sufficiently rigid. With a rigid reservoir the curves for any one gas, or gaseous mixture, would coincide at any rate in those portions corresponding to considerable intervals of time; but the inevitable difference in the initial conditions of the experiments must in general prevent entire coincidence in portions corresponding to short intervals of time. (3) The dry air curves are with this apparatus the lowest on the diagram. To us this result was unexpected; but Professor Tait had foreseen it as a consequence of the change of dimensions of the apparatus. (4) As in the preliminary experiments, the curves for air containing olefiant gas and for air containing water vapour occupy the same region of the diagram. The relative positions of the curves may be used to determine the relative absorptive powers of the gaseous mixtures. (5) The curves for air containing different quantities of olefiant gas occupy positions extending over a considerable area of the diagram, and they are higher the greater the percentage of olefiant gas (from ·032 up to 1·1). By determining a sufficient number of such curves a scale of absorptive power may be formed, to which the absorption of air containing known quantities of vapour may be referred. With our apparatus it was impossible to form such a scale accurately for the reasons given above. But an approximate result is given by our experiments. The curve for air with 1·3 per cent. of water vapour (not saturated) has above it the two curves for air with 0·2 per cent. of olefiant gas, and below it the two curves for air with 0·06 per cent. of olefiant gas. Hence we may conclude that the absorption of air containing 1·3 per cent. of water vapour is between that of air containing 0·06 per cent. and that of air containing 0·2 per cent. of olefiant gas. With a rigid reservoir it would be possible to determine exactly the constitution of mixtures of air and olefiant gas, and of air and water vapour having equal absorptive powers.

The above experiments were made in Professor Tait's laboratory during the summer vacation of 1882. By the time they had advanced thus far my vacation was at an end, and I could not wait to get a new reservoir constructed and to complete them. I hope Professor Tait may be able to complete them at an early date.

I must mention with gratitude the enthusiastic assistance rendered me by Mr Lindsay. His cheerful contempt of failure and his ready resource in difficulty contributed largely to whatever of success we attained. We are deeply indebted to Professor Crum Brown for the use of apparatus necessary for the making of olefiant gas. Of course Professor Tait took a most lively interest in our results, and we had at all times the benefit of his advice.

4. Note on the Compressibility of Water. By Professor Tait

To test by an independent process the accuracy of the unit of my pressure gauge, on which the estimated corrections for the "Challenger" deep-sea thermometers depend, it was arranged that H.M.S. "Triton" should visit during the autumn a region in which soundings of at least a mile and a half could be had. A set of manometers, filled with pure water, and recording by the washing away of part of a very thin film of silver, were employed. They were all previously tested, up to about 2½ tons weight per square inch, in my large apparatus. As I was otherwise engaged, Professor Chrystal and Mr Murray kindly undertook the deep-sea observations; and I have recently begun the work of reducing them.

The first rough reductions seemed to show that my pressure unit must be somewhere about 20 per cent. too small. As this was the all but unanimous verdict of fifteen separate instruments, the survivors of two dozen sent out, I immediately repeated the test of my unit by means of Amagat's observed values of the volume of air at very high pressures. The result was to confirm, within 1 per cent., the accuracy of the former estimate of the unit of my gauge. I then had the manometers resilvered, and again tested in the compression apparatus. The results were now only about 5 per cent. different from those obtained in the "Triton." There could be no essential difference between the two sets of home experiments, except that the first set was made in July, the second in November,—while the temperatures at which the greatest compressions were reached in the "Triton" were at least 3° C. lower than those in the latter set. Hence it seems absolutely certain that water becomes considerably more compressible as its temperature is lowered, at least as far as 3° C. (the "Triton" temperature). This seems to be connected with the lowering by pressure of the maximum density point of water, and I intend to work it out. It is clear that in future trials of such manometers some liquid less anomalous than water must be employed.

Another preliminary result, by no means so marked as the above, and possibly to be explained away, is that by doubling (at any one temperature) a high pressure we obtain somewhat less than double the compression. This, however, may be due to the special construction of the manometer, which renders the exact determination of the fiducial point almost impossible.

5. Note on an Application of Mendeleieff's Law to the Heats of Combination of the Elements with the Halogens. By Mr A. P. Laurie. Communicated by Professor Crum Brown.

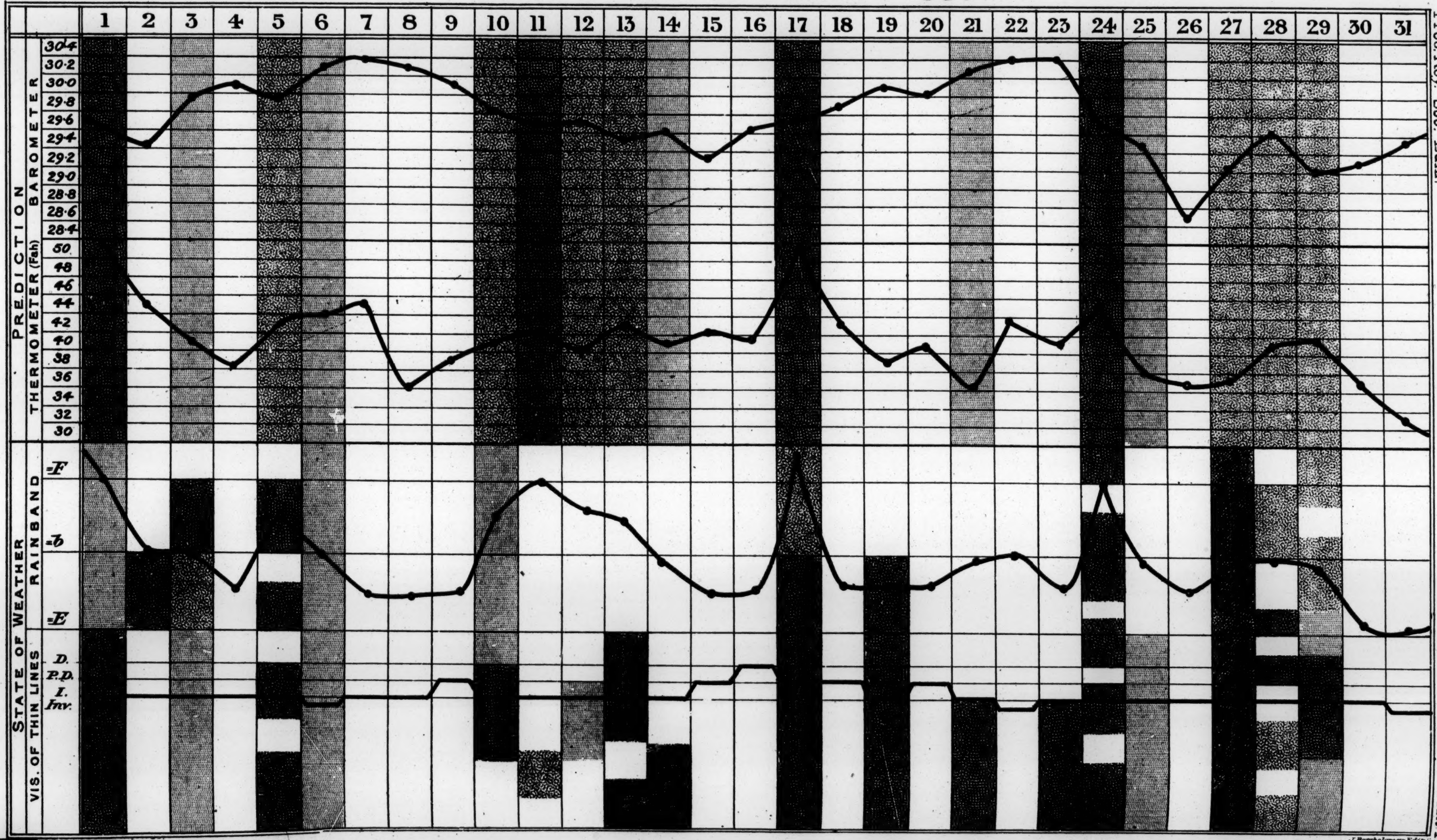
Monday, 15th January 1883.

PROFESSOR MACLAGAN, Vice-President, in the Chair.

The Chairman, in accordance with the Laws, announced to the meeting the names of proposed new Foreign and British Honorary Fellows, to be submitted for Ballot at the Second Meeting in February, viz.—*As British Honorary Fellows*:—Sir Joseph Dalton Hooker, Dr William Spottiswoode, Professor Alexander William Williamson, Colonel H. Yule. *As Foreign Honorary Fellows*:—Professor Luigi Cremona, Dr Julius Hann, Professor Charles Adolphe Wurtz.

Bert Kill, Dett

CHART FOR JANUARY 1883



J. Bartholomew Edinr.

Proc. Roy. Soc. Edinr.

Vol XII Plate 1

The following Communications were read :—

1. The Diurnal Variation of the Force of the Wind on the Open Sea and near Land. By Alexander Buchan, M.A.

2. On the Semitic and Greek Article. By the Rev. Dr Teape.

3. On the Nature of Solution. By W. W. Nicol, M.A., B.Sc.

4. On the Relative Electro-Chemical Positions of Wrought Iron, Steels, Cast Metal, &c., in Sea Water and other Solutions. By Thomas Andrews, Assoc. M. Inst. C.E., F.C.S. Communicated by Professor Crum Brown.

BUSINESS.

The following candidate was balloted for and declared duly elected a Fellow of the Society :—Dr R. Peel Ritchie.

Monday, 29th January 1883.

THOMAS STEVENSON, Esq., M. Inst. C.E., Vice-President, in the Chair.

1. Observations of the Rainband from June 1882 to January 1883. By Hugh Robert Mill, B.Sc., F.C.S. Communicated by Professor Tait. (Plate I.).

The series of observations to be described was undertaken in order to ascertain how far a small pocket spectroscope could be relied upon for the prediction of rain, with a view to its popular use for that purpose.

The instrument employed was Hilger's smallest sized direct-vision spectroscope, its length being one inch and a half, and its diameter half an inch. It was furnished with the ordinary adjustable slit, and had no special provision for the exclusion of dust. It is desirable, however, to use an instrument which has the eyehole protected by a plate of thin glass, and the slit covered with a thicker plate. In this case care must be taken to keep the glass free from scratches, which greatly obscure the spectrum.

When the spectroscope is to be used the slit is made as narrow as possible, and the focus adjusted until the spectrum appears bright and clear, with the black solar absorption lines crossing it vertically. If there is dust on the slit each grain appears drawn out into a thick black line running through the spectrum horizontally. When these horizontal lines are seen the slit should be cleaned by gentle brushing with a camel-hair pencil.

The spectrum of clear sky or a bright cloud, in the instrument used, is a coloured strip apparently about an inch long and half an inch wide. On one side a band of red, apparently $\frac{3}{16}$ths of an inch wide, emerges from blackness and shades into a $\frac{1}{16}$th inch strip of yellow, which merges into a quarter inch space of green, passing into an equal area of blue which dies away in hardly visible violet. Two or, in favourable circumstances, three black lines (*a*, B, C) are seen in the red, one (D) appears to separate the red from the yellow, a wide nebulous line divides the yellow from the green, several very thin lines appear in the green together with two thicker ones (E and *b*), and in the beginning of the blue there is a still darker line (F); besides which a glimpse may sometimes be had of other lines in the darker part of the spectrum beyond F. On looking directly at the sun many of the lines are split up into a number of very fine components, and the whole spectrum seems ruled with lines intensely black and geometrically narrow, most of which are invisible in diffused light. The nebulous line between the yellow and green is usually mistaken for the rainband at first, for it varies in intensity from time to time. A more particular observation shows that its intensity at any time is proportional to the sun's nearness to the horizon, but it appears to be sometimes affected by other causes. Professor Piazzi Smyth has shown that this is a dry air absorption band, and he defines it as "a function of dry air and low sun." The real rainband cannot be seen by itself in the little spectroscope, but an acquaintance with the spectrum soon shows that the width of the D-line is not constant, and that when widest it seems to shade off gradually towards the red, resembling a line ruled by a fine pen with a very small hair in its point. It can easily be shown that this widening is not due to a widening of the solar sodium absorption line, by looking at the sky spectrum through the flame of a Bunsen lamp faintly tinged yellow with a sodium salt. The D-line proper is thus replaced by a brilliant yellow streak, and the rainband is seen as a black line clinging to its red side. This narrow blurred line represents the hundreds of thin lines produced by the absorptive power of the water-vapour in the atmosphere, which can be seen by using an instrument of sufficient power; and although it is never seen alone or measured by itself, it can be employed as a valuable weather indicator.

The rainband was always observed by looking as near the horizon as possible, so as to take advantage of the greater depth of air seen through; the focus was carefully adjusted to give the sharpest possible definition of the solar lines, and then the intensity of the band together with the D-line was noted. The rainband has been represented by the letter π, and the compound line, which was always measured, may be written shortly as $D+\pi$.

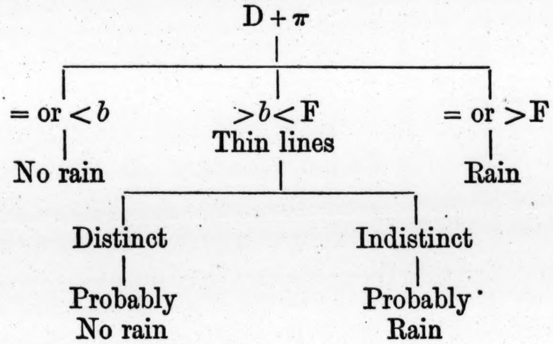
The great difficulty in recording observations is to obtain a constant scale of intensities. It has usually been the practice to judge of the intensity of the band by the eye, and to record it on a scale of 1 to 5 or 1 to 10, or else to measure it in terms of the low-sunband. The former plan possesses the disadvantage common to all purely mental scales, that there is no guarantee of the intensity which is represented by a certain figure one day being recognised as corresponding to that figure on another occasion. Changes in the illumination of the spectrum or in the condition of the observer can hardly fail to make some difference. The second plan is free from this defect to a great extent, but it is inconvenient, for beginners at least, because of the diurnal variations of the low-sunband. Various mechanical arrangements were tried in order to furnish a scale which would remain constant and could be readily reproduced, but the results of the experiments were not very satisfactory, and it therefore seemed advisable to employ a relative scale supplied by the spectroscope itself. The spectrum observed was so small that the principal Fraunhofer lines were brought near enough to be used as standards of comparison, and as the moisture in the air does not affect their relative intensities, the three most prominent (E, *b*, and F) were fixed upon as the units of the scale. The three increase in darkness in the order E, *b*, F, and they are, roughly speaking, darker in proportion to their distance from D. The method of measuring by this scale does not altogether get over the objection attached to the use of a mental scale, although that objection is reduced to a minimum; and the method at best is only applicable to small instruments. A spectroscope of sufficient dispersion to split D, or even *b*, in diffused light would entirely alter the appearance of the lines, and the rainband would appear as a *band* incapable of comparison with them. With the small spectroscope used on a clear sky the D-line appears about equal to E in intensity when the rainband is at a minimum. As the band increases the D-line appears wider, becoming in turn equal to *b*, equal to F, and greater than F. In this way six shades of intensity may be easily distinguished, and these may be represented shortly as—

$D+\pi=E.$
„ $>E<b.$
„ $=b.$
„ $>b<F.$
„ $=F.$
„ $>F.$

The words *wide*, *dark*, *black*, and *intense*, when applied to the rainband and the larger spectral lines, mean the same thing, for it is difficult to say whether a large rainband makes the D-line apparently blacker, or wider, or both, when viewed by the small spectroscope.

Another point of some importance in the prediction of rain is, as has been pointed out by Mr Rand Capron, the visibility of the thin lines in the green. These vary greatly in distinctness, being sometimes invisible and at other times very apparent, but it is difficult to avoid changing the value of the words used to express the different degrees of visibility. A long and intimate acquaintance with the spectrum in its different appearances is necessary in order to overcome this difficulty.

A regular record of the intensity of the rainband has been kept since June 1882, and the weather which followed within twelve hours of each daily observation at 9 A.M. has also been noted. Other meteorological observations were subsequently introduced to supplement those of the rainband, but during the first seven months the latter alone were considered, and a prediction founded thereon was written down each morning. The degree of intensity warranting a prediction of rain was, of course, entirely a matter of experience, each success or failure modifying to a certain extent the basis of the next prediction. At first it was only necessary to use the lines b and F for comparison, since $D + \pi$ was very rarely $< b$ during the months of June, July, August, and September. It was soon observed that rain seldom fell within twelve hours when the D-line at 9 A.M. appeared less than or equal to b, and that rain almost always followed when it appeared equal to or greater than F. Intermediate intensities were much more common, and in order to make predictions in these cases the degree of visibility of the thin lines in the green was taken into account. From the daily observations in the month of June the following table for predicting was drawn up:—



This table held closely during July. In that month the intensity was = or $> F$ on fourteen occasions, and rain followed on thirteen of these. The intensity was $> b < F$ with thin lines indistinct seven times, and rain followed six times; on six days the intensity was the same, but the thin lines were distinct, and rain (in each case only a slight shower) followed on three. Once the intensity was $= b$, and it was followed by a slight shower. The table was also applicable, though less accurately, to August, September, and October, but in November its predictive power completely broke down. The intensity was = or $< b$ twenty-four times in that month, and rain followed on fourteen of these days. The probable reason of this is the low temperature which prevailed, in consequence of which a small quantity of water-vapour produced saturation, which was thus indicated by a fainter rainband than in previous months. A new table of predictions required to be framed for the winter months, in which the intensities $D + \pi > E < b$, and $= E$ were considered.

The following table (Table I) shows the number of times which the rainband attained each intensity in each of the seven months, and how often it was followed (within twelve hours) by rain in each case :—

TABLE I.

1882. Month.	$D+\pi>F$.	Rain followed.	$D+\pi=F$.	Rain followed.	$D+\pi>b<F$. Thin Lines.				$D+\pi=$ or $<b$.	Rain followed.
					Indistinct.	Rain followed.	Distinct.	Rain followed.		
June, . .	8 times	6 tms.	4 times	4 tms.	3 tms.	2 tms.	6 tms.	4 tms.	9 times	5 tms.
July, . . .	11 „	11 „	3 „	2 „	8 „	7 „	6 „	3* „	1 „	1* „
August,† .	4 „	4 „	10 „	5 „	6 „	3 „	10 „	1 „	0 „	0 „
September, .	3 „	3 „	9 „	6 „	9 „	3 „	5 „	1 „	4 „	0 „
October, . .	7 „	6 „	4 „	4 „	9 „	6 „	2 „	0 „	8 „	3 „
November, .	0 „	0 „	3 „	3 „	1 „	1 „	2 „	2 „	24 „	14 „
December, .	4 „	4 „	2 „	2 „	7 „	5 „	1 „	1 „	12 „	5‡ „
Total, . .	37 „	34 „	35 „	26 „	43 „	27 „	32 „	12 „	58 „	28 „

*Very slight showers. † Observations this month were made at Callander.
‡Rain or much snow.

The following summary (Table II) shows that the probability of rain falling increases with the increase of intensity of the rainband in a very regular manner. When $D+\pi$ was $=$ or $<b$ rain followed more frequently than might be expected, but fourteen of these occasions were in the cold month of November and five in December, and on many occasions there were only slight showers.

TABLE II.

$D+\pi$	Number of times.	Rain followed.	
		No. of times.	or per cent.
$=$ or $<b$	58	28	48
$>b<F$ Thin lines distinct	32	12	37 } 50
$>b<F$ Thin lines indistinct	43	27	63 }
$=F$	35	26	74
$>F$	37	34	92

The dependence of the rainband on the probability of rain is perhaps more clearly seen when one or two very slight showers on an otherwise fine day are classed as "no rain," and this is evidently a fairer way of estimating the predictive power than by considering a day on which "no rain" was predicted and a trifling shower occurred as a failure. A better plan would be to omit all days on which there were only slight showers, and simply take account of those on which there was no rain at all or else heavy rain, sufficiently heavy, for example, to interfere with outdoor work. In Table III. it is seen that the increase in intensity of the rainband is not followed by a perfectly regular increase in the percentage of rainy days, which is probably due to the scale not being perfectly uniform, and that a dark rainband is a much surer prognostic of a wet day than a faint one is of dry weather.

TABLE III.

Intensity $D+\pi$	Percentage of rain following.	Percentage of "no rain" following.
$=$ or $<b$	27	73
$>b<F$	38	62
$=F$	74	26
$>F$	92	8

This table represents the results for seven months, classing one, or at most two, slight showers as "no rain." Since the extreme values of the intensity of the rainband illustrate its predictive power most strikingly, it may help to show the importance of such observations, if a short account is given of the various cases in which $D+\pi$ was registered as $>F$ and as $<b$ during the seven months under consideration. During these months there were thirty-seven cases of $D+\pi>F$, and on three of these no rain followed within twelve hours. Two of these mornings of failure were very misty, but the third was bright and clear. On ten occasions heavy showers came on in the *afternoon.* On one of these occasions (July 1st) there was a thunderstorm, on another (September 1st) the rainband, according to Professor Piazzi Smyth, was the darkest for the whole year. There were heavy showers in the *forenoon* on three days and showers at irregular intervals on ten, two of which (July 6th and August 13th) were accompanied by thunderstorms. On nine days rain fell continuously, and on two there was continual snow. There were thus 8 per cent. of unsuccessful, and 92 per cent. of successful, predictions when the rainband was at its maximum. It was found that on twenty-eight occasions $D + \pi$ was $< b$. On eighteen of these no rain whatever followed for twelve hours, on four one, or at most two, slight showers followed. On four considerable rain, and on two a considerable amount of snow fell. There were thus 21 per cent. of erroneous, and 79 per cent. of successful, predictions when the rainband was its minimum of intensity.

Table IV. gives a summary of all the predictions made from June to December 1882, with the fulfilments. These predictions were made from spectroscopic evidence alone, the barometer and thermometer were not consulted. In the table "no rain" means that no rain whatever fell during the twelve hours following the prediction. This, as explained when describing Table II., accounts for the apparently greater accuracy of "rain" than "no rain" predictions.

TABLE IV.

	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
Rain predicted,	17	22	20	21	20	12	13	125
,, followed,	15	20	12	12	16	11	11	97
Per cent. fulfilled pred.,	88	91	60	57	80	92	85	78
"No rain" pred.,	13	7	10	9	10	18	13	80
,, followed,	7	3	9	8	7	9	8	51
Per cent. fulfilled,	54	43	90	89	70	50	62	64
Total predictions,	30	29	30	30	30	30	26	205
,, fulfilments,	22	23	21	20	23	20	19	148
,, percentage,	74	79	70	67	77	67	73	72

The success of a prediction has been judged of uniformly from the frequency, duration, and intensity of the showers which followed, and not by the rainfall in inches. This was done because the situation of the observing station (in the south side of Edinburgh) was unfavourable for the use of a rain-gauge; and as each prediction was made for a period of twelve hours, the published rainfall for the vicinity for periods of twenty-four hours did not form a trustworthy index of the success of a prediction. If observations could be made twice or three times a day, so that each prediction would cover a shorter time, and if the intensities of the rainband in different directions were compared each time, much more decided proofs of the utility of the spectroscope as a short-period predictor might reasonably be expected. Situation and circumstances rendered it possible only to make an observation on the north-west sky each morning at 9 A.M., hence all the results described in this paper are deduced from observations in that direction at that hour. If possible the observation should be made on a piece of clear sky, but the spectrum of the light from clouds is not necessarily untrustworthy. Out of 120 consecutive predictions 75 per cent. of those made on a clear, and 73 per cent. of those on a cloudy, sky were verified. The spectroscope cannot be used in a thick mist or a snowstorm, and its indications in frosty weather are usually too faint to be of much value, although it may almost always be relied upon to predict a thaw at least one day beforehand.

Remarks on the Chart for January 1883.

During the month of January 1883 the barometer and thermometer were observed as well as the spectroscope, and the accompanying chart embodies the results obtained.

The shading in the upper half of the column allotted to each day represents the prediction, that in the lower half shows the degree of fulfilment. When the upper half is blank (*e.g.*, the 2nd) "no rain" was predicted, and a blank lower half (*e.g.*, the 4th) shows that no rain fell. A very light shading in the upper half (*e.g.*, the 3rd) denotes a prediction of "probably a little rain," slightly darker (*e.g.*, the 5th) means "some rain," while the very dark (as on the 1st) stands for "rain." The lower half shows the rain which followed up to 9 P.M., the length, position, and darkness of the parts shaded representing approximately the duration, time, and heaviness of the showers. Snow is shown by peculiar shading, as on the 27th. The first and second curves join the points at which the barometer and thermometer stood each morning at 9 o'clock, and the third exhibits the intensity of the rainband in a similar manner. A rise in this curve corresponds to an increase in the intensity of the band. The fourth line, which could scarcely be represented by an ordinary curve, illustrates the visibility of the thin lines in the green on the scale—

Invisible, Indistinct, Pretty distinct, Distinct,

but for reasons already stated this curve is less reliable than the others.

Summing up the results, it is seen that on sixteen days the prediction was that more or less rain would fall, and that this was verified on fourteen, or 87 per. cent. "No rain" was anticipated on the remaining fifteen days, and on twelve of them, or 80 per cent., there was no rain. The mean percentage of successful forecasts (83·5) is not altered by omitting those days on which only slight showers occurred. The 11th and 19th are the most marked instances of erroneous prediction shown on the chart. It is interesting to notice the general closeness with which the rainband curve follows that of temperature. This is strikingly shown for maxima on the 1st, 17th, and 24th, and for minima on the 4th, 8th, 26th, and 31st. When the divergence of the curves is considerable the nature of the weather to follow is always decided. Thus, when the thermometer is low and the rainband strong, rain is certain to follow, as it did on the 3rd and 21st for example, and when there is a high thermometer and a faint band there will be no rain, for instance, the 7th, 15th, and 20th.

One great secret of successful rainband predicting seems to lie in making proper allowance for the temperature, and the direction and force of the wind have also a share in modifying the data.

2. The Theory of Monopressures applied to Rhythm, Accent, and Quantity. By the Rev. J. L. Blake. Communicated by Professor Crum Brown.

3. On the Effect of Oil on a Stormy Sea.

By Mr John Aitken.

The calming effect of oil on troubled waters is so well known and so often referred to, that we might have expected there would, by this time, have been a considerable amount of written information on the subject. This calming effect of oil is not only well known, but it has also become so stereotyped by constant repetition, that it seems to have acquired the stamp of classical antiquity upon it, yet one is surprised to find that reference to it in early writers is strangely conspicuous by its absence. Our knowledge of the subject seems to have lived almost entirely in tradition.

It is only within the last year that anything like definite attempts have been made to test practically and on a large scale the effect of oil on the waves of the sea. The first of these experiments were made in March last at Peterhead by Mr Shields of Perth, who has taken great interest in the matter. Later on in December last he made other experiments at the entrance to the Aberdeen harbour. The place selected by Mr Shields for the latter experiments was within the entrance channel, at a point about 270 yards inside the furthest point of the north pier, and at rather more than 700 yards outside the entrance to the tidal harbour. The channel is at this point somewhat contracted, and has a breadth of about 240 yards. To distribute the oil over the water, Mr Shields erected a hand pump on the north pier, and connected it with a pipe 1 inch in diameter, which was laid on the bottom of the channel and carried out more than half way across it. The oil was pumped through this pipe, and escaped near the middle of the channel by three valves and roses placed across it 50 feet apart, so as to distribute the oil over some breadth. The oil pumped through the pipe rose to the surface in small globules and spread itself over the water. The effect was very marked and decided. The oil smoothed over the waves and prevented the formation of dangerous crests; the entrance to the harbour was thus made much safer for vessels. Mr Shields deserves great credit for these experiments made on so large a scale, and it is much to be regretted that this method of calming the waves is not less expensive. Each of the experiments at Aberdeen lasted for one hour; the value of the oil used in each was about £20, and though the effect remained for an hour after the pump was stopped, yet the expense does seem great. I am not aware if any experiments were tried to use less oil, but it is evident that it is possible to use too much. There is just one quantity which will give the maximum effect; more or less will not do so well.

Since the experiments at Peterhead and Aberdeen called attention anew to the subject, a number of explanations of this peculiar action of oil have been given; none of these, however, appear to me to account for the facts. I have therefore ventured to place the following experiments and a theory built upon them before this Society; and though this theory may not appear to some to explain all the phenomena, yet, as it calls attention to certain effects of an oily film, the importance of which has not previously been taken notice of, I trust the subject may not be uninteresting, and may at least be of some little aid in helping forward a proper understanding of this most interesting and difficult subject.

The wonderful effect of oil on water has suggested to many observers the idea that the effect was due to the oily film offering less resistance to the wind than the clean water surface; that the oil so to speak greased the wind. The first thing therefore which seemed necessary to be done was to test whether there was any truth in this supposition; to arrange some experiment to ascertain whether there was less friction between air and an oily film than between air and a clean film. The method adopted was to place some water in a circular vessel, and arrange a jet of air so that it should blow over the surface of the water, and cause it to take up a motion of rotation. Under these conditions the rate of rotation of the water would—if the pressure of the air jet was kept constant—depend on the amount of friction between the air and the water surface. If the oil decreased the friction the water would be driven less quickly under an oily than under a clean film.

In order to measure the amount of motion communicated by the air to the water, a horizontal paddle, completely submerged, was hung in the middle of the vessel by means of a fine platinum wire, the upper end of the wire being attached to a torsion-head. A needle, rigidly attached to the paddle, indicated on a circular scale the amount of torsion produced by the moving water, that is, showed the amount of energy communicated by the air jet to the water. The air jet was supplied from a gasometer, which could be loaded to different pressures.

The following is the method adopted in working this instrument. The circular glass vessel was carefully washed, and filled with water up to a certain height, which was accurately adjusted for each experiment, so that the water was always exactly the same distance below the jet. Air at a low pressure was then blown over the water, and the angle of torsion noted. The pressure in the gasometer was then raised, a stronger current was blown over the water, and the reading again taken. In this way a number of readings were taken at different pressures, the angle of course increasing with the pressure. After taking two or three series of such readings to get an average for the clean water surface, a little oil was put on the water, and another series of readings taken. The result of these experiments was that there was no decrease in the amount of deflection after the oil was added to the water; which shows that as the air communicated the same amount of motion to the oily surfaced water as it did to the clean surface, therefore oil does not reduce the bite, grip, or friction of the air on the water.

In working with this apparatus it was found very difficult to get constant readings. On making a new experiment, after washing the glass vessel, some change seemed to take place, and the readings for the corresponding pressures were not always the same as the previous ones. The general result, however, was that the oil in a few cases slightly decreased the readings, but in most cases it increased them a little. The difference in the readings in the experiments with clean water, seems in some way to be connected with the resistance offered by the film where it is attached to the sides of the vessel, and the slight increase given in most cases by the oily film may possibly be due to the weakening of this film by the oil.

In the experiments described, the surface film simply circulated in the vessel and but little free surface was developed; if, however, a division plate was put across the vessel just deep enough to stop the easy circulation of the film, an interesting and curious result was obtained. When the pressure of the air jet was low, so that it did not greatly agitate the surface, and the surface film could circulate quickly enough, there was then scarcely any difference between the readings given by the clean and by the oily surface. But when the pressure rose and the agitation of the water became great, a sudden increase in the amount of deflection took place; but this increase always occurred at a lower pressure with the oily than with the clean film, the explanation of which would seem to be, that when greatly agitated by the air new surface film requires to be rapidly developed, and, as it gets no aid from the contracting film in front, this new surface film can be developed by a lower air pressure in the weak oily film than it can in the stronger clean film. This extreme condition of matters, however, seems never to present itself in nature.

Experiments such as these made in the laboratory on water films are in the highest degree unsatisfactory. Since I have begun them I have found this surface film of water to be far more delicate and variable than I had previously any idea of, and find it almost impossible to get it in a uniform condition. If the experimenting vessels are not cleansed with something to destroy the last trace of soap used in washing off the oil, if the vessel or the water is touched with the fingers or exposed for any length of time to the air of the laboratory, changes take place in the surface tension. It therefore seems that more satisfactory experiments might be made on large sheets of water. As yet I have been unable to do anything in this direction except one experiment, which, on account of the smallness of the sheet of water, may not be of much value.

The object of the experiment was to see if the wind communicated less horizontal motion to the surface water under an oily than under a clean film, which would be the case if the wind has a less grip or bite of oily than of clean filmed water. It will be observed here that I leave out of consideration any question as to a possible slipping of the oily film over the water, without dragging the water film underneath along with it. If there is any depth of oil, its upper surface cannot slip over the lower more easily than the same depth of water could, as oil is more viscous than water, though we might imagine the bounding surface might prevent the formation of eddies and the deepening of the motion; but we have seen from the experiment with the jet of air on water in a circular vessel, that there is no evidence of any slipping forward, as the body of water underneath takes up the same amount of motion whether the surface is oily or not.

In the experiments made on the small sheet of water, the rate of motion communicated by the wind to the surface water was tested by means of small circular floats 9 cm. diameter and 4 cm. deep. The floats were submerged 2 or 3 m. and only a thin stem projected above the water. Two of these floats were dropped into the pond near that end from which the wind was blowing, and at some distance apart, at right angles to the direction of the wind. These floats were allowed to drift to the opposite end of the pond to see that the rate of motion was the same at both sides. Some oil was now poured over the water at one side, and other two floats started over the same routes as the first two. It was found that the two floats still travelled at the same rate, that oiling had not perceptibly altered the rate of motion. We might almost have expected a different result, on account of the waves on the clean water affording a better catch to the wind, but possibly this advantage might be lost by the eddies and irregular motions resulting from the waves.

I do not place any great reliance on the accuracy of these experiments, and the last one is evidently on too small a scale; yet I think if the effect of oil on troubled waters is due to its reducing the grip of the wind, the reduction would require to be very great, so great that there would have been some evidence of it even in these imperfect experiments.

There is, however, another consideration which indicates that the oil does not produce its effects by reducing the friction between the air and the surface of the water. Oil itself when exposed to wind is driven into waves very much as water is. It may be that the waves are not so marked in oil as in water, but this is chiefly due to the greater viscosity of the oil. This was seen in some experiments made on a small scale for the purpose of observing the effect of wind on a body of oil. For this purpose two shallow vessels about half a metre square were placed in an exposed part of a field, where the wind could blow freely over them. One vessel was filled with oil, and the other with water as a standard with which to compare the movements of the oil. It was observed that if the oil was thick and viscous there was but little effect, and scarcely any surface circulation produced; and it required a strong breeze to drive the oil into waves. But with paraffin oil, which is thin and mobile, the result was very different; it seemed more easily driven into waves than even water. This was probably due to the oil having a less specific gravity than the water, but I think the comparatively greater agitation observed in the oil was partly owing to the water surface not being quite clean, on account of the paraffin vapour which could not easily be prevented from condensing upon it, so that the water was not so easily driven into waves as it ought to have been. When a little of the paraffin oil was put on the surface of the water it made it much quieter than the body of oil.

When we pour a little oil on a wind-driven surface of water, the effect is so marvellous, the smoothing of the waves is so instantaneous, that the imagination is carried away, and we at once attribute to the oil some wonderful property, though we may not understand what that property is. When, however, we examine its action and consider what is taking place, we see that it is not doing, it is preventing something which previously took place, and we are driven to consider what it has prevented. In fact, we are driven to examine how the wind gives rise to waves. It will therefore be necessary for us, before saying anything about the effect of oil, to examine how wind acts on the surface of water, and gives rise to waves; we shall afterwards better understand the effect of oil.

The upper surface of water, where it is in contact with the air, is covered with a film having a well-known and definite tension. The tension of this film is always in a state of equilibrium, and the slightest stress acting on a part of it causes the surface to move in the direction of the strain. When a part of the film moves, new film or free surface is formed in the rear of the moving area, and covers the water which was previously covered by the displaced film, while the film in front of the moving film is diminished in area, part of it being absorbed by the water. *No work is required to develop this new film, as the work done by the contracting part of the film in front is equal to the work spent in developing the new film in rear of the moving area.* The result of this is, that the slightest stress acting on the surface of the water determines a movement of that surface, its motion being in no way checked by the surface tension.

Suppose, now, the wind to blow over the surface of a sheet of water, which, for the present, we will suppose to be quite motionless, and for clearness let us suppose further that the wind strikes the water at only one place. The result is that the surface film where the air strikes is blown forwards, and in sliding over the water it produces waves, one set of waves being produced in front of the moving film, and another set produced by the moving film being raised in the act of being driven over the water underneath. Now if, instead of supposing the wind to act at only one place, we consider what actually takes place in nature, namely that the wind strikes the surface of the water at all points, but more strongly at some points than at others, on account of the eddies produced in the air in its passage over the resisting water, it is evident under these conditions that certain parts of the surface film are more powerfully urged forwards than others, and the water yielding to this unequal action is driven into a series of waves, having a gradually accumulating effect. This effect is intensified by one side of the wave being thrown up into such a position that the wind acts more powerfully on it than on the other side, or than on a horizontal surface.

Let us now look at the action of the same water surface, but over which there has been thrown a film of oil. The surface has entirely changed its character. *New free surface or film cannot now be developed without the expenditure of energy.* If we try to move forwards one part of the surface, we find its motion is resisted by the tension of the surface behind it increasing on account of the removal of the oil, and the tension in front of the moving area does not increase but diminishes. The forward movement of the film is therefore checked. Suppose now the wind to blow over such a surface, the parts where the wind strikes strongest will tend to move forwards, but will be unable to do so on account of the increasing tension behind and reduced tension in front. Further, the parts upon which the wind strikes least are drawn forwards by the greater tension in front of them and behind the parts tending to move most quickly, and where the wind has developed an increased surface tension. The result of this is, that the wind cannot drive forwards *isolated patches of film* or surface so as to cause waves, but the whole of the surface is caused to advance at nearly a uniform rate, and the formation of waves is thereby prevented.

In illustration of these points the following experiments were shown:—Two large shallow rectangular vessels with parallel sides were prepared. Both vessels were filled with water, and over the surface of one was put a little oil, the other being kept clean. Narrow strips of paper, about 2 or 3 cm. broad, were cut to such a length that they would when expanded by the water be slightly shorter than the breadth of the vessels. One of these strips of paper was put across the middle of each vessel. For the purpose of moving these papers over the surface of the water two threads were previously attached to each of them near their ends. Taking first the vessel with the clean surfaced water, the paper strip was by means of the threads moved into its position right across the middle of the vessel. It was shown that the paper strip could be moved backwards and forwards over the surface of the water, with the very slightest expenditure of energy, the film not in the slightest degree resisting the movement, the free surface or film in front contracting quickly and pulling as strongly as the new film which was developed in the rear. It was further shown that after the paper strip had been moved backwards or forwards into any position, it remained where it was put.*

Turning to the oily surfaced water, it was shown that the movement of the paper strip on its surface was resisted, the threads by which it was moved becoming tightened when it was dragged from its original position; and further, that when the tension was discontinued the paper returned to the place from which it had been moved. It did not matter whether it was moved backwards or forwards, it always returned to its original position, so long as no surface film was allowed to pass round the ends and get to the other side of the paper. The tension on the threads in these experiments represents the resistance which an oily film offers to the forward movement by the wind of isolated areas of surface film.

This resistance is not, however, the most important effect of the oil. It is, so to speak, the secondary effects that are most powerful in checking the formation of waves. On oily surfaced water the forward moving area reduces the tension in front, and causes the film there to advance on account of the greater tension in front; it also increases the tension behind, and so causes the film in the rear to be drawn forwards, and the irregular film advance which takes place in clean water is converted into a uniform and regular advance by the oil. This was illustrated by the arrangements used in the previous experiments. A small piece of paper to act as a float to show the movements of the surface film, was dropped on the clean water and near the long narrow strip of paper. The long strip was now moved away from the float, when it was seen that its movement had no influence on the float, as it remained in its original position, and further, the float did not move when the strip was moved towards it. The long strip might be moved in any direction, but the small piece of paper had no tendency to move till it was almost touched by it. The reason for this want of sympathy, so to speak, between the two pieces of paper is due to the surface tension being everywhere alike, and free surface appears and disappears without any disturbance of the surface tension.

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* This was found to be an excellent test of the cleanness of a surface film. If there is the slightest impurity on the surface it gets collected in front of the strip, and the paper cannot be moved quite to the end of the vessel without meeting with resistance.

When the same experiment was repeated on the oily water the result was very different. There was now a bond of union between the two pieces. If the long piece was drawn away the small piece followed it, if moved up to it the small piece receded from it These movements of the float were pointed out to be the result of the disturbance produced in the surface tension by the movement of the strip. The forward movement of the strip causes the oily film in front to become thicker, its tension therefore becomes less, and it tends to expand forwards, or rather is drawn forwards, by the thinner film in front, and the free surface which is developed in the rear of the strip is rapidly covered by the advance of the oily film which brings with it the paper float. It was shown from this that the forward movement by the wind of isolated areas of oily film was not only resisted, but that their forward movement gave rise to forward movements of the film, both in front and in rear of them. From these experiments it will be seen that a clean water surface acts towards the horizontal force of the wind as if it had no surface tension whatever, whereas an oily film acts very much as if the water was covered with a thin skin of india-rubber. Or the stability of a clean water surface might be compared to that of a perfect sphere on a perfectly horizontal plane, and the stability of an oily surface to that of an egg on its side.

The effect of this regulating influence of the oil on the surface tension may be illustrated in another way, which shows that the uniform rate of advance of the surface film produced by the oil prevents the formation of waves or ripples. If the long narrow strips of paper in the previous experiments are moved quickly over the surface of the water, the following effects are seen. On the clean water, the advance of the strip gives rise to a series of very evident and well-marked waves or ripples in front of it, whereas on the oily surface no waves are formed. The film is seen simply to contract in front of the moving paper. In order to regulate the motion of the strips in the different experiments, a convenient arrangement is to attach to a pendulum the threads which are fixed to the paper strips, and, by drawing the pendulum and strip aside to the same amount in each experiment, we can regulate its drag on the strip with considerable precision. If we wish to compare the effects of equal amounts of energy spent in each case, so as to get results corresponding to equal blasts of wind, then the pendulum should be light; and if we wish to see the effects of equal rates of motion the pendulum ought to be heavy.

When we examine the surface of a sheet of water under the action of the wind, we observe that the floating bodies on its surface are all moving forwards—all are carried forwards by a surface current, but a closer examination of the smaller bodies lying close to the surface shows that the advance of the surface film is a jerky one; one part of the surface advances quickly, then stops, then another part gets into rapid movement, and the general appearance is that of a patchy and irregular advance of the surface film. With oil on the surface all this is changed; the floating bodies are all now seen to be hurrying forward at a nearly uniform rate, the oil having entirely checked the patchy and irregular advance which gave rise to waves.

Paradoxical as it may at first sight appear, it is nevertheless true that the weakening of the surface film by the oil is a source of strength to the surface of the water, and enables it to resist the action of the wind. The oil, in fact, makes the surface film inextensible to small strains, and so regulates the action of the wind that waves are prevented, and no effect produced save a nearly uniform sliding forward of the surface.

Supposing the explanation here given to be true as regards the formation of small waves or ripples, yet a cause so small seems at first sight quite inadequate to explain so wonderful an effect as that of oil on a stormy sea, and I can easily imagine the question being asked, What effect can this very weak resistance of the surface film have on the mighty energy of an all but irresistible ocean wave? They indeed seem to have but little relation to each other. Before coming to any conclusion on this point it will be necessary for us narrowly to examine what really is the effect of oil on already formed waves.

Let us therefore examine any small sheet of water over which there is passing a series of well-formed waves, and see if the explanation we have given of the formation of small waves or ripples applies here to the effect of oil. As we look upon the waves as they pass us, we observe that their surface is very far from being smooth; on the contrary, a regular series of waves are being formed by the wind on the surface of the large ones. These waves are small at the bottom of the large waves, and grow in size as they approach the top. In fact, the wind is repeating on the waves very much the same process as when it first begins to blow on calm water. This action on the large waves is, however, infinitely more rapid than on the calm water, as the wind is blowing with far greater violence than ever it does on calm waters; and further, the slope of the surface of the water on large waves being towards the wind, causes its action to be much more powerful than on a horizontal surface. Now, the breaking of large waves is very evidently connected with the formation of these smaller ones which form on them, and grow in strength towards their tops, where they form crests and break, thereby adding dangerous qualities to the wave.

We have already seen that oil prevents the formation of small waves on calm water; it will therefore prevent the formation of small waves on the surface of large ones, and will thereby prevent the formation and breaking of their crests. In order to test whether this conclusion is correct or not, let us again examine the surface of the small sheet of wind-driven water, and, while watching the waves as they glide past, let us pour over them a little oil. At once a change takes place; small waves no longer form on the already made waves, the latter simply continue on their course smoothed and rounded on their surface. We see that the oil by precluding the formation of small waves, has prevented the roughness and the pointed crests which previously formed on the waves and which break when the wind is sufficiently violent. Further, it seems probable that the smoothness of the large waves, produced by the oil preventing the formation of small waves on their surface, must not be neglected, as it will reduce the bite or grip of the wind, and thereby reduce its action on the already formed waves.

Carrying out this process of reasoning, we see how the great waves of the ocean are increased and made dangerous by exactly the same process which we have seen in operation in smaller ones, only intensified and made more dangerous by the greater surface of the large waves, while the oil, by preventing the formation on their surface of smaller waves, hinders the development of dangerous crests. That oil has no other effect on the great waves of the sea is confirmed by the experiments made at Aberdeen. I am informed by Mr Smith, the harbour engineer, that there was no perceptible lowering of the waves after the water was covered with oil. Its action was simply to smooth over the waves and prevent them from cresting or breaking, an effect of great importance and value in making the entrance to the harbour safer during stormy weather.

It will be observed, according to the explanation here offered, that oil has no power to calm waves; it simply acts by preventing their formation and growth in certain ways. The resistance to extension offered by an oily film will also have, no doubt, a slight effect in checking the up and down motion of the water, but the practical effect of this resistance must be very small and quite unappreciable.

It may be as well for us to note that the general question of the growth of waves has not been under consideration here, our attention having been entirely confined to the effects of surface tension on their birth and development.

Properly to understand the vast importance of so small a cause as the slight difference of tension produced by the oily film, we have only to remember that large waves have their genesis in tiny ripples, which by the cumulative action of the wind grow into large waves, and the oil, by preventing the formation of the ripple, strangles the wave in its birth. On the other hand, the perfectly balanced tension of the surface of clean water is as the "letting out of waters," as "the thin edge of the wedge," as the stone detached from the top of the mountain which brings along with it the irresistible avalanche. Prevent the beginning and the disastrous results are obviated.

It might be thought that the difference between the surface tension of clean water and oily water is too small to give rise to surface currents or film movements of sufficient velocity to produce these effects, and that the film would break, that is, that all the oil would be blown away before the film behind could be dragged forwards. The ease with which the film glides over the water, and the velocity with which one part of the film can drag another is, however, much greater than might at first be imagined. Take the following examples:—Drop some oil on the surface of water; note the extremely rapid spread of the oil. Now, the rapidity of that surface movement is the measure of the power which that particular oil confers on the water of dragging forwards surface film. In fact, the rapidity of that advance is the same as that with which the film can rush forwards in rear of a wind-driven area. That surprisingly rapid movement seems sufficient to perform the duty the theory here propounded lays upon it.

Another experimental illustration, better suited to the lecture-room, is made by taking a small piece of paper, say 10 cm. long by 2 cm. broad, and attaching to the opposite sides of the ends of it two small pieces of camphor. This is easily done with a little bees-wax. If this piece of paper with the attached camphor be placed on the surface of clean water, it at once starts into a rapid motion of rotation, which will be kept up for hours, till all the camphor is dissolved if the vessel of water is large enough. The rapid movement is here due to the tension of the pure water surface on one side of the strip being greater than the tension of the weak solution of camphor on the other. The paper is thus dragged round by the unbalanced tension of the clean surface. Or we may vary the experiment by placing a number of pieces of camphor on one side of the paper. If this paper is placed on the surface of a pond, it will be rapidly drawn over the water.

Take another example of the wonderful effect of this difference of surface tension. Fill two vessels full of water; put a little oil on one of them, then dust some fine powder over the surface of the water in both vessels. The powder must be free from greasy matter—well-burned ashes sifted through fine wire gauze does well. Now direct a jet of air vertically downwards on the surface of the water. When this is done on the clean water, it will be observed that the very slightest possible current of air causes the surface film and the dust floating on it to move away from the place where the air strikes, leaving a perfectly dustless surface. Repeat the experiment with the oily surface. It will now be found that however hard you blow you cannot drive back the oily surface, and that when the jet of air is sufficiently strong to cause a deep depression in the surface of the water, the dust particles are seen rushing at certain places into the depression and running out at others with a velocity perfectly surprising.

This easy slipping of the surface film may also be seen when the water is in motion and the film at rest. Recently I observed a small stream flowing quickly enough to give rise to slight disturbance of the surface flatness, and yet the surface film was quite motionless. While the stream was flowing underneath, the advance of the surface film was checked by some weeds and grasses forming a floating bridge across the stream. If the surface had been quite clean this would not have taken place, but a film of weak tension had collected in front of the grasses, caused by impurities derived probably from the bed of the stream, and not from the air, as the stream was in the country, and far from towns and factories. The tension of the surface in front being less than that behind, the strain put on it by the under current was not great enough to cause it to be absorbed in front of the floating obstruction. A somewhat similar effect may be noticed when we stir up—not round—a cup of tea and then drop in a little cream. The surface film movements of the oily tea are seen to stop while the tea mixing with the cream can still be seen in active movement. The drag of the tea on the surface film is not sufficient to develop new free surface against the resistance of the increasing surface tension of the cleaner film, and all surface movements are stopped, save circular ones, which do not require the development and absorption of free surface. These surface movements are sometimes stopped by a rigid pellicle forming on the surface, but they are also stopped when no such covering is present.

It is generally recognised that rain and small floating bodies have an influence on the water somewhat similar to that of oil, and tend to calm its surface. In the case of the rain it seems possible that the great amount of free surface added by the drops causes the surface film to expand and act somewhat in the same manner as oil, as we know that water dropped on the surface of water causes an expansion of the film where the drop enters. There is, however, another way in which these rain drops act. In falling on the surface, the drops mix up the shallow film current—which makes the ripple—with the water underneath, and thus destroy it. Much of the calming effect of rain is, however, no doubt due to the falling of the wind, which generally accompanies rain.

Small floating bodies act on the surface of water in different ways. Professor James Thomson, in a paper * containing his own and Sir William Thomson's observations on "Calm Lines on a Rippled Sea," shows that these calm lines are associated with long sinuous lines of floating bodies, such as leaves, weeds, &c., and they attribute the calmness in part to the damping action of these bodies acting like floating breakwaters, and destroying small ripple undulations. The author of the paper referred to also points out that part of the calmness is due to oily scum or film; he also shows how these floating bodies and scum may be collected in long sinuous lines by the surface currents produced by descending currents due to difference of temperature. These surface currents, coming from opposite directions, bring with them floating bodies and scum, which collect over descending areas or lines. That part of the calmness of these lines is due to the film at the place having a low surface tension produced by some impurity is confirmed by my own observations made under somewhat different conditions. If we examine the surface of a canal when the wind is blowing very nearly straight along it, we see that on the side of the canal towards which the wind inclines to blow, there is a strip of smooth glassy water extending for about a meter from the bank. This smoothness is evidently not caused by the protection of the bank, but is due to impurities on the surface collected there by the wind, as the calm area has a well-marked line of demarcation, and is present when the wind is almost directly along the canal, the other side of the canal having no corresponding calm area.† The calm areas in the canal in the cases

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* "Calm Lines on a Rippled Sea," *Philosophical Magazine*, Sept. 1862 (Fourth Series), vol. xxiv. p. 247, and *Proceedings of Philosophical Society of Glasgow*, 15th Feb. 1882.

† I have also observed that rapidly flowing streams when they enter still water often have calm areas in front of them. This calmess seems to be due to the rapid absorption of the surface film of the stream which here takes place, and any surface impurities brought by the stream get concentrated and become sufficiently great to reduce the surface tension.

observed were not due to floating bodies, as scarcely any were present. Further, an examination of water where a number of small floating bodies were present, showed their action to be quite distinct from that of oily scum. Small floating bodies destroy the waves, but wind can ripple or roughen the surface of the water amongst them, whereas oily scum does not destroy waves, but prevents ripples or darkening of its surface.

My observations on the appearance of the canal suggest another way, in addition to the one given by Professor Thomson, in which oily scum and small floating bodies collect near other floating bodies. One evident effect of floating bodies is to check the forward advance by the wind of the surface film of water, and the shallow surface current is thus converted by floating bodies into a deeper but slower current. The result of this is that more surface film with its impurities comes to the floating bodies than goes away. Surface impurities therefore tend to collect in the neighbourhood of these floating breakwaters.

In addition to this action of small floating bodies in destroying waves there is another way in which small bodies, such as ice-spicules, &c., act, and smooth the water by preventing the formation of ripples. Small floating bodies *prevent the formation of* ripples or waves by deepening the current, and so offering a resistance to the rapid advance of any part of the upper film of water. Weeds and grasses lying on the surface of the water prevent the irregular advance of the surface film, by the resistance they offer to the irregular advance of any part of it, and by the drag or pull they exert on the water behind the parts tending to move quickly. Weeds and grasses thus tend to promote uniform rate of advance at all parts of the surface, and thereby prevent the formation of ripples or waves.

It is obvious that all oils will not have the same power to prevent the formation of waves. It is therefore desirable that we should have some information as to the value of different oils or other substances for this purpose. The value of an oil will depend on a number of things, the most important of which are (1) the rate at which the particular oil will distribute itself over the surface of the water. This will depend greatly on the difference of tension between the surface of clean water and the surface of the water covered with the oil. The greater this difference the more powerful will that particular oil be. The rate of movement will also probably depend on the viscosity of the oil. The value of the oil will depend (2) on the amount of it required to cover unit area. With these two properties will require to be taken into consideration a third point, namely, the market price of the oil. Besides these points, attention will require to be given to the specific gravity of the oil, its solubility in water, and the rate of its evaporation into air.

I have been able as yet to give attention to only one of these points. A few oils have been tested to find the amount to which their presence reduced the surface tension of water. Most of the methods for ascertaining the surface tension of a liquid are not suitable for testing that of an oily film. In the oily surfaced water we have not only to measure the tension of the oil, but also the tensions of the bounding surfaces of the oil and the water. As these combined tensions vary with the amount of oil on the surface, the ordinary methods of testing are not suitable, as they do not admit of uniform conditions.

It may be as well to remark here, that there is not, as many people suppose, a distinct line of demarcation between the surface covered with clean film and that covered with oily film. That is, the oil wherever present does not always reduce the surface tension to the same amount. On the contrary, there is no line of demarcation between the clean and the oily film; the one shades imperceptibly into the other, and the amount to which the oil reduces the surface tension depends on the quantity of oil present. Very little oil gives a very slight reduction of tension, and as more is added the tension becomes less till a minimum is reached, after which no reduction takes place. This condition is indicated by the oil ceasing to spread rapidly. Its movements after this stage is reached depend upon whether the oil is lighter or heavier than water. If lighter, it very slowly spreads itself over the water, its movements being now due to gravity. If the oil is heavier than the water, it collects and forms on the surface depressions, which deepen, and ultimately a large drop of oil breaks away and slowly sinks in the water. The breaking away of these drops forms a very beautiful experiment, and the slowness of the process gives an opportunity of studying some interesting phenomena.

For testing the surface tensions an indirect way of measuring the tension of the surface of water in a vessel was adopted. This was done by finding the amount of pull necessary to raise a flat disc off the surface of the water. The disc in rising brings with it a certain quantity of water, and the amount of water lifted depends on the height to which the disc can be lifted above the surface before the film yields, and, as this depends on the strength of the film, the weight of water lifted forms an indirect way of measuring the strength of the film. The apparatus used consisted of a circular disc 4·5 cm. diameter. In order that this disc might hang horizontally as nearly as possible, it was accurately turned on the end of a metal rod. The upper end of this rod was hung to one end of the beam of a balance. To the other end of the beam was hung a glass tube, inside which was placed a scale with the zero point near the top of the tube. A tall narrow vessel full of water was placed underneath, and so that the tube hung in the water. The tube was loaded with mercury till it just balanced the metal disc with the beam of the balance horizontal, and the tube immersed in the water up to the zero point. In order to get good contact between the water and the metal disc, a coating of plain collodion was put on the disc. After all the collodion solvents had escaped, the apparatus was ready for a test. The vessel with water to be tested was placed under the disc and at the correct height, the beam, when the disc touched the water, being slightly inclined downwards at the disc end. The tall vessel of water was now slowly lowered. As the level of the water gradually went down, the weight of the graduated tube increased. While the level of the water descended, a careful watch was kept to observe at what number on the scale the disc broke away from the water.

The object of using the submerged tube was that it allows of an increase of weight being put on very gradually and without shock.

With this instrument the different readings for the same sample of water always agreed easily to 1 per cent., though they varied 3 or 4 per cent. for different samples if the vessel which held the water was not carefully cleaned.

Owing to the principle of the construction of this instrument, it does not give absolute readings, nor do the readings of the scale represent numerically the relative strengths of the different films, so that readings got from the different oily surfaces do not correctly represent their relative values. The readings, however, enable us to arrange the different oils in the relative order of their strengths.

A few of the more easily obtained oils were tested with this instrument. In the following table these are arranged in the order of their tensions on the surface of water, beginning with the weakest tensions, or those which would be most powerful in checking the formation of waves:—

Sperm oil.
Linseed oil.
Rape seed oil.
Cloves, Oil of.
Cod-liver oil.
Olive oil.
Anise seed oil.
Almond oil.
Paraffin oil.
Lubricating oil (mineral).
Mineral oil.

The first few oils in this list are the best, and do not differ much from each other. Cod-liver oil is not quite so good, olive is decidedly less powerful, while the three mineral oils are by far the worst of all, as they reduce the surface tension very much less than the others. The same result was, I believe, got in the experiments at Aberdeen. Mineral oil was there found to be less effectual in calming the waves of the sea than seal or cod oil.

4. The following communication from the Astronomer-Royal for Scotland was read by Professor Tait:—

In case you should not have any better account of it from those who keep hourly, or perhaps continuous, observations, you may like to mention to the Society this evening, on no more than my twelve-hour testimony,—the occurrence of a decided meteor, of meteorology, last night.

The *maximum* outside temperature yesterday about 2 P.M. was 40°·5, and the *minimum* temperature, self-registered, for the night was 37°·0; while at 10 A.M. this morning the then temperature was 41°·0, or nothing very different from the day before. And yet for all that, and some time during the darkness of the night, there had been an influx of warm wind, with a temperature of 51°·0!

It lasted, too, sufficiently long to impress an inside *maximum* self-registering thermometer as well; for while this should not have read through the night higher than 52°·0, it was found this morning to have marked 61°·5.

One consequence of this has been, that while the snow of last Saturday held its own very tenaciously all yesterday on the top of the Calton Hill, there is not the smallest particle of it visible this morning on any side, or in any nook and corner; while the grass of the hill looks fresher, greener, healthier than it has done through several years past, at the same date.

The present winter began indeed in a very threatening manner with its great snow-storm early in December. But, as I had the opportunity of mentioning in the Registrar-General's return for that month, the appearance would probably be found to be exceptional, rather than characteristic of the whole season: for we were too far advanced at the present time into the *middle* of a sun-spot cycle, to fear any of those thoroughly and throughout severe winters which, according to the Edinburgh Royal Observatory observations, have never occurred but at, or near, the *beginning* of such a cycle.

5. Diagnoses plantarum novarum Phanerogamarum Socotrensium, etc.; quas elaboravit Bayley Balfour, Scientiæ Doctor et in Universitate Glascuensi rerum botanicarum regius Professor. Pars Tertia.

PLUMBAGINEÆ.

87. **Vogelia pendula**, *Balf. fil.*: fruticosa ramis pendulis; foliis plus minusve spathulatis; inflorescentia diffusa paniculata; sepalorum marginibus membranaceis vix bullatis intus glandulis instructis; corollæ lobis sinu non-mucronulato.

Socotra, in montibus Haghier. B.C.S. No. 411. Schweinf. No. 586.

SAPOTACEÆ.

88. **Sideroxylon fimbriatum**, *Balf. fil.*: arboreum glabrescens ramis rugosis; foliis petiolatis exstipulatis ellipticis v. oblongo-ellipticis v. obovatis obtusis, basi subcuneatis, subtus pallidis; fasciculis sessilibus; pedicellis brevibus validis; calycis lobis suborbicularibus; corolla calyce longiore; staminum filamentis glabris; staminodeis petaloideis obovatis fimbriatis; fructu rostrato.

Socotra, in convallibus prope Kadhab. B.C.S. No. 339.

OLEACEÆ.

89. JASMINUM ROTUNDIFOLIUM, *Balf. fil.*: fruticosum scandens velutino-puberulum; foliis trifoliolatis, foliolis petiolulatis subæqualibus v. terminali majore rotundatis v. ellipticis obtusis; cymis paniculatis terminalibus; floribus majoribus pedicellatis; calyce truncato; corollæ tubo elongato, lobis 5–6 oblongis; baccis sæpe 2 globosis.

Socotra, in montibus non infrequens. B.C.S. No. 173. Schweinf. No. 649.

APOCYNEÆ.

SOCOTORA, *Balf. fil.*

Calyx brevis 5-partitus basi intus glandulosus segmentis acutis. Corolla late campanulata, tubo brevissimo, fauce squamis 2-seriatis connatis instructa, exterioribus 5 flagelliformibus sinubus oppositis, interioribus 10 rotundatis obliquis per pares lobis oppositis; lobi 5, oblongo-ovati, obtusi, emarginati, ecaudati, antice rubro glandulo pannosi, contorti, dextrorsum obtegentes. Stamina 5 tubo affixa, filamentis validis, decurrentibus, basi dilatatis et inter se squamis connatis; antheræ exsertæ subovatæ, acutæ, circum stigma conniventes non adhærentes, connectivo lato dorso villoso, loculis basi cassis in appendiculas breves rotundatas productis. Pollen granulosum in quoque loculo in massas 2 cohærens. Discus 0. Ovarii carpella 2 conjuncta; stylus validus brevis; stigma dilatatum, vertice depresso-conicum, lateraliter 5-gonum, galeis 5 cinctum et appendicula stigmatica ab quoque angulo pendula instructum; ovula in quoque loculo numerosa. Folliculi lineares divaricatim adscendentes et basi connati. Semina lanceolata trigono-compressa apice comosa; albumen copiosum firmum; cotyledones lineari-oblongæ, rectæ, planæ, crassiusculæ, radicula supera longiores.—Frutex scandens, glaber, crassiusculus, aphyllus. Folia cataphyllaria opposita. Flores solitarii axillares.

Genus monotypicum bene distinctum in tribu Echitidearum inclusum.

90. S. APHYLLA, *Balf. fil.*: species unica in montium clivis prope Galonsir crescens. B.C.S. No. 327.

ASCLEPIADACEÆ.

91. **Ectadiopsis brevifolia**, *Balf. fil.*: fruticosa rigida erecta foliis sparsis brevibus sessilibus sæpe fasciculatis oblongis v. obovatis obtusis emarginatis mucronatis v. apiculatis; cymis sessilibus; floribus brevissime pedicellatis.

Socotra, in campis calcareis. B.C.S. Nos. 583, 615.

92. **Ectadiopsis volubilis**, *Balf. fil.*: fruticosa volubilis; foliis diversis ab forma lineari ad obovatam variantibus subsessilibus sæpe fasciculatis; cymis pedunculatis; floribus breviter pedicellatis.

Socotra, frequens. B.C.S. Nos. 259, 696. Schweinf. Nos. 472 667.

Mitolepis, *Balf. fil.*

Calyx 5-partitus, glandulosus, segmentis oblongis obtusis. Corolla campanulata, tubo brevi, lobis angustis linearibus obtusis contortis dextrorsum obtegentibus. Coronæ squamæ 5, basi fusiformes, apice filiformes, medio tubo corollæ affixæ qua paullo breviores. Stamina prope basin tubi affixa, filamentis liberis; antheræ erectæ, basi stigmati adhærentes, apice conniventes, acutæ, liberæ, dorso glabræ. Pollen granulosum appendicibus oblongo-ellipticis corpusculorum applicitum. Stigma depresso-conicum medio 2-lobatum. Folliculi divaricati teretes striati subtiliter puberuli. Semina comosa.—Frutex erectus multo-ramosus. Folia opposita fasciculata linearia. Flores solitarii breviter pedicellati.

Genus monotypicum Periplocearum *Ectadis* et generibus vicinis verisimiliter affine.

93. **M. intricata**, *Balf. fil.*: species unica in montibus Haghier crescens. B.C.S. No. 508. Schweinf. No. 651.

Cochlanthus, *Balf. fil.*

Calyx urceolatus, alte 5-fidus lobis longe acutis recurvis, intus basi 5-squamatis, squamis dentatis. Corolla campanulata alte 5-partitus, tubo brevi, segmentis angustis obtusis valide sinistrorsum contortis dextrorsum obtegentibus. Coronæ squamæ 5, tubo corollæ affixæ, breves, validæ, crassæ, apice 2-lobatæ, basi leviter latiores, subcomplanatæ tubo corollæ æquilongae et supra gynostegium conniventes. Stamina intra coronam affixa, filamentis brevissimis distinctis; antheræ deltoideæ, stigmati adhærentes, conniventes, apice in appendices breves subulatos abrupte reflexos productæ, imberbes. Pollen granulosum, corpusculorum appendicibus linearibus paullo concavis. Stigma late conicum vertice bilobatum; ovula numerosa. Folliculi crassi breves oblongo-ovoidei leves divaricati. Semina comosa.—Frutex alte scandens. Folia opposita glabra. Cymæ in paniculos corymbosos pedunculatos terminales dispositæ. Flores pedicellati.

Genus monotypicum Periplocearum, corolla, coronæ squamis et antheris ab aliis bene notatum.

94. C. SOCOTRANUS, *Balf. fil.*: species unica in montibus Haghier crescens. B.C.S. No. 525.

95. **SECAMONE SOCOTRANA**, *Balf. fil.*: volubilis ramis ferrugineo-tomentosis; foliis obovatis; cymis subsessilibus; corollæ tubo intus lineari-villoso; stigmate capitato spongioso; folliculis breviter pubescentibus.

Socotra, in montibus et campis. B.C.S. No. 179. Schweinf. No. 739.

96. **VINCETOXICUM LINIFOLIUM**, *Balf. fil.*: volubile glaucum ramis flagelliformibus; foliis filiformibus; cymis extra-axillaribus lateralibus longe pendunculatis; corona 5-fida lobis carnosulis obtusis.

Socotra, in campis frequens. B.C.S. No. 208.

97. **MARSDENIA ROBUSTA**, *Balf. fil.*: fruticosa robusta erecta ramulis petiolisque pubescenti-tomentosis; foliis cordatis v. ovatis obtusis; inflorescentiis petiolis brevioribus; corollæ laciniis oblongis obtusis, tubo intus dense villoso; stigmate rostrato obscure lobato; folliculis pubescentibus.

Socotra, prope Galonsir et Kadhab. B.C.S. No. 522. Schweinf. No. 741.

98. **BOUCEROSIA SOCOTRANA**, *Balf. fil.*: ramis tetraquetris marginibus angulato-sinuatis, lobis in spinas productis; corolla atrosanguinea; corona alte 5-fida; segmentis apice trifidis, lobo medio minimo incurvo, lobis lateralibus erectis subulatis.

Socotra, in campis abundans. B.C.S. No. 524. Schweinf. No. 740.

GENTIANEÆ.

99. Exacum cæruleum, *Balf. fil.*: suffruticosum humile glabrum; foliis sessilibus v. subsessilibus ovatis trinerviis; floribus pentameris magnis terminalibus solitariis v. in dichasia pauciflora dispositis; calycis lobis alatis; corollæ segmentis cæruleis ellipticis; antheris lateraliter ad medium dehiscentibus.

Socotra, in montibus Haghier crescens ad altitudinem supra 3000 ped. B.C.S. No. 403. Schweinf. No. 672.

100. Exacum affine, *Balf. fil.*: annuum erectum ramosum; foliis ellipticis v. ovatis acutis longe petiolatis 5-nerviis; floribus pedicellatis cernuis 5-meris; calycis lobis late alatis; corollæ lobis obovatis violaceis; antheris ad apicem dehiscentibus.

Socotra, in ripis viridibus fluviorum abundans. B.C.S. No. 82. Schweinf. No. 466.

101. Exacum gracilipes, *Balf. fil.*: annuum erectum ramosissimum; foliis lanceolatis acutis petiolatis 3-nerviis; floribus graciliter pedicellatis cernuis 5-meris; calycis lobis anguste alatis; corollæ lobis obovatis cæruleis; antheris ad medium lateraliter dehiscentibus.

Socotra, in locis aridis frequens. B.C.S. No. 84.

BORAGINEÆ.

102. Cordia obovata, *Balf. fil.*: arborea; foliis petiolatis obovatis v. oblongo-obovatis apice obtusis et dentato-crenatis, basi cuneatis, subtus subscabridulis, supra tuberculatis; cymis paucifloris terminalibus; pedicellis validis brevissimis; floribus mediocribus 4-fidis; calyce enervio extus dense pubescente, subfructu cupulæformi glabro; corolla omnino glabra; fructu aurantiaco ovoideo 1–3-loculari.

Nom. Vern. Abēteh.

Socotra, per totam insulam abundans. B.C.S. Nos. 277, 427. Schweinf. No. 379.

103. Cordia obtusa, *Balf. fil.*: arborea; foliis petiolatis ellipticis v. elliptico-obovatis obtusis v. late acutis integris glabris siccitate nigricantibus; cymis pseudo-axillaribus paucifloris; pedicellis validis

brevibus; floribus ignotis; calyce sub fructu cupulæformi glabro; drupa ovoidea aurantiaca 1-loculari.

Socotra, in montibus prope Galonsir. B.C.S. No. 325.

104. HELIOTROPIUM (MONIMANTHA) DENTATUM, *Balf. fil.*: annuum ramulis a collo patentibus; foliis linearibus v. lineari-lanceolatis dentatis hispidis; inflorescentiis laxe ramosis paucifloris; corollæ tubo calyce longiore; styli lobis non exsertis; nucibus glabris.

Socotra, in campis prope Galonsir et Tamarida. B.C.S. No. 40. Schweinf. Nos. 781, 789.

105. HELIOTROPIUM (HELIOPHYTUM) ODORUM, *Balf. fil.*: suffruticosum plus minusve scabrido-puberulum; foliis alternis petiolatis oblongis v. oblongo-ovatis basi subcuneatis; spicis conjugatis ebracteatis; fructu bifido, pyrenis bilocularibus bispermis.

Socotra, in montibus Haghier. B.C.S. No. 181. Schweinf. No. 461.

106. HELIOTROPIUM (ORTHOSTACHYS) NIGRICANS, *Balf. fil.*: suffruticosum intricato-ramosum decorticans ramulis strigosis angulosis; foliis suboppositis breviter petiolatis parvis, ab forma elliptica ad formam obovatam variantibus, nigricantibus strigosis; inflorescentiis paucifloris bracteatis; corollæ tubo calyci æquilongo, limbo magno; stigmate truncato vix bilobato; nucibus scabridis.

Socotra, prope Gharriah. B.C.S. No. 581.

107. TRICHODESMA SCOTTI, *Balf. fil.*: fruticosum; foliis magnis ellipticis acutis basi angustatis sparsim setosis; floribus magnis in corymbos magnos terminales dispositis; nuculis magnis $\frac{2}{3}$ poll. longis anguste marginatis.

Socotra, in montibus altissimis. B.C.S. No. 438. Schweinf. No. 623.

108. TRICHODESMA MICROCALYX, *Balf. fil.*: annuum hispido-asperum; foliis ellipticis v. ovatis, inferioribus petiolatis; floribus mediocribus; calycis segmentis lanceolatis subfructu non auctis; nuculis deltoideis dorsaliter valide muricatis non marginatis.

Socotra, in regionibus altioribus Haghier montium. B.C.S. No. 538. Schweinf. No. 632.

109. TRICHODESMA LAXIFLORUM, *Balf. fil.*: annuum sparsim

setulosum; foliis ovatis v. oblongo-ovatis, inferioribus petiolatis; inflorescentiis laxe ramosis; floribus parvis; calycis segmentis lanceolatis subfructu non auctis; nuculis obovatis dorsaliter minute tuberculatis margine alatis.

Socotra, frequens. B.C.S. No. 532. Schweinf. No. 788.

CYSTOSTEMON, *Balf. fil.*

Calyx 5-partitus, segmentis linearibus, fructifer auctus nuculas includens. Corolla campanulata, supra staminum insertionem dilatata, fauce nuda ampliata; lobi 5, ovati, acuminati, imbricati, per anthesin patentes revoluti. Stamina 5, medium tubum versus affixa, exserta, filamentis obcordatis expansis inflatis basi annulo villoso cinctis; antheræ oblongo-lineares, longe acuminatæ, erectæ, conniventes, cohærentes. Ovarii lobi 4, distincti, gynobasi parvæ planæ impositi; stylus filiformis erectus, stigmate subintegro; ovula erecta. Nuculæ 4, erectæ, acutæ, angulatæ, verrucosæ, areola basalari. Semina recta; embryo rectus, cotyledonibus ovatis crassis planoconvexis, radicula supera.—Herba canescens, setoso-hispida pilis simplicibus. Folia alterna. Cymæ scorpioideæ terminales, bracteis parvis inferioribus foliaceis. Flores azurei, pedicellati.

Genus monotypicum *Boragini* forsan maxime affine.

110. C. SOCOTRANUM, *Balf. fil.*: species unica montes altos calcareos Socotræ incolans. B.C.S. No. 309. Schweinf. No. 593.

CONVOLVULACEÆ.

111. IPOMŒA (QUAMOCLIT) LACINIATA, *Balf. fil.*: annua depressa radiatim ramosa ramis prostratis; foliis laciniatis pinnatisectis longe petiolatis sparsim pilosis; floribus subsessilibus in axillis solitariis; sepalis exterioribus subtrifidis; corolla angusta; ovario rostrato; seminibus maculosis pubescentibus.

Socotra, in campis arenosis circa Galonsir. B.C.S. No. 100.

112. CONVOLVULUS FILIPES, *Balf. fil.*: suffruticosus inermis ramosissimus ramis scopariis filiformibus strigosis v. subsericeis; foliis linearibus strigosis; floribus longe pedicellatis laxos racemos terminales formantibus; calycis lobis corolla multo-brevioribus; ovario glabro; seminibus pubescentibus.

Socotra, per insulam totam abundanter crescens. B.C.S. No. 116. Schweinf. No. 238.

113. **Convolvulus sarmentosus**, *Balf. fil.*: subpulvinatus inermis lignosus perennis argenteo-sericeus ramis brevibus basi congestis cum ramulis paucis virgatis sarmentosis; foliis basalibus rosulatis oblanceolatis, superioribus ovato-acutis v. lanceolatis; floribus pedicellatis breves racemos simplices formantibus; ovario glabro; seminibus puberulis.

Socotra, in montibus calcareis ad alt. 1500 ped. B.C.S. No. 302.

114. **Porana obtusa**, *Balf. fil.*: fruticosa scandens; foliis oblongo-obtusis; sepalis subfructu paullo auctis; corollæ lobis induplicato-valvatis; stylis duobus.

Socotra, inter scopulos apud extremitatem occidentalem campi Kadhab scandens. B.C.S. No. 355.

115. **Breweria pedunculata**, *Balf. fil.*: suffruticosa virgata incana pubescente-tomentosa; foliis oblongis subsessilibus; floribus valide pedunculatis in axillis solitariis; calyce corolla breviore; ovario hirto; stylis 2.

Socotra, in campis calcareis. B.C.S. No. 158.

116. **Breweria glomerata**, *Balf. fil.*: suffruticosa nana prostrata lignosa albido-tomentosa ramis congestis; foliis ovatis v. ellipticis subsessilibus; floribus in capitula hirta terminalia confertis; calyce corolla longiore; ovario hirto; stylis 2.

Socotra, in campis prope Galonsir. B.C.S. No. 114. Schweinf. No. 258.

117. **Breweria fastigiata**, *Balf. fil.*: suffruticosa argenteo-sericea fastigiatim denseque ramosa ramis strictis; foliis approximatis subimbricatis lanceolatis sessilibus; floribus sparsis in axillis subsessilibus; sepalis apice conniventibus corolla brevioribus; ovario glabro; stylo breviter bilobato.

Socotra, in campis calcareis abundans. B.C.S. Nos. 73, 273. Schweinf. No. 349.

SOLANACEÆ.

118. **Withania Riebeckii**, *Schweinf.*: frutex habitu foliisque *W. somniferæ* sed ab ea differens calyce profunde diviso et fructifero non vesicoso oreque subaperto.

Nom. Vern. Ābab.

Socotra, frequens in palmetis ad Tamarida et Galonsir. B.C.S. No. 32. Schweinf. Nos. 326, 794.

SCROPHULARINEÆ.

119. CAMPTOLOMA VILLOSA, *Balf. fil.* : herba perennis villosa; foliis rotundato-cordatis crenulato-dentatis; floribus paucis in racemos terminales breves dispositis; capsula calycem excedente.

Socotra, in locis scopulosis ad 3000 ped. alt. B.C.S. No. 237.

120. CAMPYLANTHUS SPINOSUS, *Balf. fil.* : suffruticosus intricato-ramosissimus incanus spinosus; foliis minutis crassiusculis linearibus obtusis; floribus solitariis subsessilibus axillaribus; corollæ tubo calyce duplolongiore; capsula oblonga glabra.

Socotra, in campis prope mare abundans. B.C.S. No. 101. Schweinf. No. 261.

121. GRADERIA FRUTICOSA, *Balf. fil.* : fructicosa; foliis oblongo-ellipticis v. ellipticis minute aculeolatis; floribus breviter pedicellatis racemos formantibus; corolla sesquipollicari; filamentis et antheris staminum glabris.

Socotra, in montibus Haghier ad alt. 3000 ped. crescens. B.C.S. No. 398. Schweinf. No. 634.

XYLOCALYX, *Balf. fil.*

Calyx campanulatus, ad medium v. altius 5-fidus, fructifer accrescens lignascens, laciniis angustis. Corollæ tubus vix exsertus, superne ampliatus, paullo incurvus; limbus patens, lobis 5 latis integris subæqualibus 2 posticis interioribus. Stamina 4, didynama, exserta; antheræ liberæ, glabræ, per paria approximatæ, loculis distinctis parallelis rectis, altero cujusque antheræ tenuiore. Stylus filiformis, apice stigmatoso leviter incrassato obtuso; ovula in loculis numerosa. Capsula basi globosa, apice compressa, in calyce aucto inclusa, loculicide dehiscens, valvis integris medio septiferis. Semina numerosa, obcuneata, testa foveolata.—Suffrutex rigidus, lignosus, nanus, minute aculeolatus, siccitate nigricans. Folia opposita, interdum plura alterna, oblonga v. elliptica, integra. Flores in axillis superioribus subsessiles v. breviter pedicellati, 2 bracteolati. Bracteoli calyci adhærentes, proventu lignascentes.

Genus monotypicum tribui Gerardieæ referendum atque *Micrargeriæ* et *Graderiæ* valde affine.

122. X. ASPER, *Balf. fil.*: species unica in locis aridis camporum Socotrensium crescens. B.C.S. No. 111.

ACANTHACEÆ.

123. **RUELLIA INSIGNIS**, *Balf. fil.*: fructicosa; foliis petiolatis ellipticis v. subrhomboideis obtusis, lamina glabra supra papulosa cystolithifera; floribus axillaribus solitariis; bracteolis calyce viscido brevioribus viscidis; corolla magna; capsula 4-sperma.

Nom. Vern. Ojehit.

Socotra, in montibus Haghier frequens. B.C.S. No. 376. Schweinf. No. 440.

124. **RUELLIA CARNEA**, *Balf. fil.*: fruticosa dense stellatim tomentosa et viscida; foliis cordatis; floribus solitariis axillaribus; bracteolis calyce brevioribus; corolla magna; capsula pubescente.

Socotra, in campis prope Galonsir. B.C.S. No. 510. Schweinf. No. 714.

125. **BLEPHARIS SPICULIFOLIA**, *Balf. fil.*: fruticosa nana ramulis lateralibus contractis; folia rigida oblanceolata v. sublinearia rarius subhastata spinosa; floribus solitariis terminalibus; bracteolis calyce brevioribus; calycis lobis integris.

Socotra, in campis. B.C.S. No. 183. Schweinf. No. 442.

126. **BARLERIA ACULEATA**, *Balf. fil.*: fruticosa non-spinosa fereglabra; foliis petiolatis obovatis v. subellipticis coriaceis aculeatis; floribus axillaribus solitariis; bracteolis calyce brevioribus; staminibus 2; staminodiis 3; capsula obovoidea basi vix contracta 4-sperma.

Socotra, in montibus Haghier. B.C.S. Nos. 399, 408. Schweinf. No. 553.

127. **BARLERIA TETRACANTHA**, *Balf. fil.*: fruticosa nana glabra ramis lateralibus axillaribus verticellatim tetracanthis; foliis crassis lanceolatis oblanceolatis v. obovatis apice aculeatis; floribus axillaribus; bracteolis pungente-subulatis calyci æquilongis; staminibus 4, 2 brevioribus; ovarii loculis 1-ovulatis.

Socotra, in campis frequens. B.C.S. No. 605. Schweinf. No. 374.

128. **Barleria argentea**, *Balf. fil.*: fruticosa inermis argentea canescens; foliis lanceolatis v. oblanceolatis strigulosis acutis v. sub mucronulatis; floribus in cymas bifloras axillares pedunculatas dispositis; bracteolis lineari-subulatis calyce brevioribus; stamina 2; staminodiis 2; ovarii loculis 1-ovulatis; capsula rostrata pubescente 2-sperma.

Nom. Vern. Shiramhan.

Socotra, in clivis montium. B.C.S. No. 544.

129. **Neuracanthus aculeatus**, *Balf. fil.*: suffruticosus incanus ½–1-pedalis ramulis brevibus; foliis linearibus sinuato-undulatis; spicis axillaribus brevibus; bracteis apice lignosis subulato-pungentibus.

Socotra, in campis. B.C.S. No. 502.

130. **Neuracanthus capitatus**, *Balf. fil.*: suffruticosus incanus nanus ramis elongatis decumbentibus; foliis ellipticis v. obovatis sinuato-undulatis; spicis congestis in inflorescentias capitatas aggregatis; bracteis angustis apice subulato-pungentibus.

Socotra, in campo Kadhab solum repertus. B.C.S. No. 360.

BALLOCHIA, *Balf. fil.*

Calyx 5-partitus, segmentis angustis acutis subæqualibus. Corollæ tubus longiusculus recurvatus extus pubescens intus glanduloso-puberulus, fauce ampla; limbus 2-labiatus, labio postico exteriore oblongo erecto concaviusculo breviter 2-lobato, antico 3-partito segmentis planis inter se subæqualibus lateralibus erectis intermedio intimo patente. Stamina 2 antica perfecta, fauci affixa, labio postico paullo breviora v. sublongiora, filamentis decurrentibus validis complanatis postice cum staminodiis parvis sublinearibus uncinatis subconnatis; antheræ 1-loculares, oblongæ, medio dorso affixæ, muticæ, apertæ late membranaceæ. Discus pulvinatus. Stylus filiformis apice integer obtusus v. brevissime bifidus; ovula in quoque loculo 3. Capsula oblonga, basi in stipitem solidum longe contracta. Semina 4 v. abortu pauciora, compressa, suborbiculata, rugosa, scrobiculata, retinaculis tenuibus fulta; embryo normalis.—Frutices elati v. humiles, lignosi, rigidi, inflorescentia glanduloso-puberula excepta glabri. Folia parva, integerrima, crassa. Flores flammeo-flavi v. flavidi, pedicellati, in axillis solitarii v. dichasia axillaria simplicia formantes. Bracteæ minimæ, angustæ.

Genus species tres includens *Oreacantho* valde affine sed habitu, inflorescentia, corolla et staminodiis recognoscendum.

131. B. AMŒNA, *Balf. fil.*: virgata ramulis albis sæpe subspinescentibus; foliis parvis subsessilibus oppositis v. fasciculatis oblongis obtusis margine revolutis; floribus solitariis axillaribus pedicellatis pedicellis foliis longioribus glandulosis; stylo apice bifido.

Nom. Vern. Misah.

Socotra, in campis Kadhab et Tamarida. B.C.S. Nos. 364, 430. Schweinf. Nos. 648, 700.

132. B. ROTUNDIFOLIA, *Balf. fil.*: subarborea nonnunquam nana ramulis obscure alatis; foliis brevissime petiolatis late ovatis v. subrotundatis acutis v. obtusis margine revolutis subtus albido-lepidotis; floribus in dichasia axillaria dispositis rarius solitariis, pedicellis longis glanduloso-puberulis; stylo apice obtuso integro.

Socotra, in montibus frequens. B.C.S. No. 300. Schweinf. No. 605.

133. B. ATRO-VIRGATA, *Balf. fil.*: erecta ramulis strictis nigris; foliis brevissime petiolatis elongato-oblongis v. oblanceolatis obtusis margine undulatis subtus glaucis; floribus solitariis axillaribus, pedicellis foliis multo brevioribus glabris; stylo apice breviter bifido.

Socotra, in montibus. B.C.S. No. 578.

134. JUSTICIA (GENDARUSSA) RIGIDA, *Balf. fil.*: fruticosa rigida lignosa cano-velutina; foliis minutis obovatis v. oblanceolatis; floribus spicatis axillaribus; bracteolis minutis calyce brevioribus; capsula cana strigulosa.

Socotra, in campis. B.C.S. No. 358.

TRICHOCALYX, *Balf. fil.*

Calyx alte 5-partitus, segmentis angustis linearibus acutis apice subulatis æqualibus. Corollæ tubus extus pubescens, intus glaber, limbo æquilongus paullo incurvus sursum ampliatus; limbus 2-labiatus, labio postico interiore erecto concaviusculo brevissime 2-lobato, antico oblongo patente breviter 3-lobato lobo medio extimo, palato nullo. Stamina 2, fauci affixa, labio postico æquilonga, filamentis leviter arcuatis decurrentibus; antheræ 2-loculares, loculis discretis, altero altius affixo mucronato v. submutico, altero inferiore basi calcare brevi parvo albo appendiculato; staminodia 0. Discus cupularis v. pulvinatus dentatus v. integer. Stylus filiformis apice obtusus minute 2-lobatus; ovula in quoque loculo 2. Capsula oblonga, basi in stipitem solidum contracta. Semina 4 v. abortu pauciora, compressa, suborbiculata reniformia, papilloso-tuberculata, retinaculis obtusis complanatis fulta.—Frutices parvi. Folia integra crassiuscula. Flores sordide purpurei ad extremitates ramorum in cymas densas congesti. Bracteolæ calycis segmentis similes üsque parum breviores. Gibbi 2 pilosi ab extero basi corollæ tubum intrusi.

Genus species duas includens in sectione Justiciearum locatum, *Justicieæ* affine etiamque *Isoglossæ* et *Anisotidi* sed ab omnibus calyce, corolla antherisque bene separatum.

135. T. ORBICULATUS, *Balf. fil.*: ramulis tomentoso-pubescentibus; foliis orbiculatis.

Socotra, in montibus prope Galonsir. B.C.S. 175.

136. T. OBOVATUS, *Balf. fil.*: ramulis glaucis lepidotis pilisque-brevibus puberulis; foliis anguste obovatis v. oblongo obovatis.

Nom. Vern. Elhal.

Socotra, in montibus Haghier prope Tamarida. B.C.S. Nos. 428, 541, 597. Schweinf. No. 371.

137. ANISOTES DIVERSIFOLIUS, *Balf. fil.*: fruticosus; foliis plus minusve obovatis; cymis axillaribus v. terminalibus.

Nom. Vern. Elhan.

Socotra, in montibus Haghier. B.C.S. Nos. 506, 576. Schweinf. No. 477.

138. RHINACANTHUS SCOPARIUS, *Balf. fil.*: herba subglabra scoparia ramulis striatis; foliis longis linearibus.

Socotra, prope Tamarida, B.C.S. No. 687. Schweinf. Nos. 448, 783.

ANGKALANTHUS, *Bal. fil.*

Calyx alte 5-partitus, segmentis lanceolatis acutis 3–5-nerviis subæqualibus. Corolla extus pubescens; tubus limbo brevior, incurvus, superne ampliatus, intus basi dense villosus; limbus longe 2-labiatus, labio postico exteriore ligulato truncato eroso recurvo apice spiraliter revoluto, antico subæquilongo recurvo patente lato elliptico-oblongo trifido lobis linearibus obtusis spiraliter revolutis intermedio latiore intimo. Stamina 2, fauci affixa, labio postico vix æquilonga, filamentis complanatis breviter decurrentibus; antheræ oblongæ 2-loculares sagittatæ, loculis parallelis æqualibus muticis; staminodia 0. Discus inconspicuus. Ovarium glabrum; stylus filiformis exsertus apice breviter bilobatus; ovula in quoque loculo 2. Capsula ignota . . . . .—Frutex. Folia subintegra. Flores flammeo-flavi in spicas longissimas terminales v. axillares dispositi. Bracteæ bracteolæque minutæ ovatæ. Alabastri falciformes.

Genus monotypicum Eujusticiearum ad Africanum *Himantichilum* et Brasiliensem *Schaueriam* relatum sed bene distinctum.

139. A. OLIGOPHYLLA, *Balf. fil.*: species unica in campo Nogad Socotræ crescens. B.C.S. No. 610.

140. ECBOLIUM STRIATUM, *Balf. fil.*; fruticosum ramis striatis; foliis longe petiolatis plus minusve ovatis; bracteis integris pilosis viscidis; bracteolis calyce longioribus; corollæ limbo tubo subæquilongo calyceque duplolongiore.

Socotra, in montibus Haghier. B.C.S. No. 504. Schweinf. No. 652.

Var. MINOR, *Balf. fil.*: omnino minor; spicis longioribus; bracteolis calyce brevioribus.

Socotra, abundans. B.C.S. Nos. 433, 462.

141. DICLIPTERA EFFUSA, *Balf. fil.*: annua diffusa ramosissima subglabra nitida; foliis ovatis longe petiolatis pungente-cuspidatis; dichasiis longe pedunculatis solitariis axillaribus; bracteolis viscidis lanceolatis v. oblanceolatis pungentibus; corolla bracteolis breviter longiore; capsula viscida.

Socotra, frequens. B.C.S. Nos. 117, 566. Schweinf. No. 463.

142. DICLIPTERA OVATA, *Balf. fil.*: annua parva pubescens prostrata; foliis ovatis breviter petiolatis; dichasiis breviter pedicellatis solitariis axillaribus; bracteolis sparsim viscidis; corolla bracteas longe excedente.

Socotra, prope Tamarida. B.C.S. No. 577.

143. HYPOESTES PUBESCENS, *Balf. fil.*: annua parva pubescens; foliis petiolatis ovatis; cymis paucifloris terminalibus v. axillaribus; bracteolis involucri 4 inæqualibus calyce longioribus, exterioribus

majoribus; corolla resupinata, labio postico longe mucronato; capsula pubescente.

Socotra, apud Kischen. B.C.S. No. 509. Schweinf. No. 612.

SELAGINEÆ.

COCKBURNIA, *Balf. fil.*

Calyx 5-fidus, tubulosus, lobis angustis acutis æqualibus. Corollæ tubus brevis superne ampliatus; limbus 2-labiatus, patens, labio postico 2-lobato, antico parum longiore 3-lobato lobis subæqualibus. Stamina 4, didynama, supra medium tubum affixa, exserta; antheræ versatiles, confluentia—loculares, medio vix constrictæ. Ovarium 1-loculare, 1-ovulatum; stylus apice minute bilobatus. Fruct. ignot.—Frutex incanus ramis diffusis virgatus. Folia alterna, obovata, integerrima. Flores cæsii, parvuli, in spicas breves terminales sæpe compositas dense conferti, singuli in axillam bracteæ sessiles ebracteolati. Bracteæ non involucratæ, anguste lanceolatæ, calyce parum breviores, cum calyce hirtæ.

Genus montoypicum *Globulariæ* valde affine sed ab ea ob inflorescentiam spicatam sine bracteis involucratis et corollæ differentias præcipue separatur.

144. C. SOCOTRANA, *Balf. fil.*: species unica montes Socotræ incolans. B.C.S. Nos. 262, 317, 558. Schweinf. Nos. 568, 610.

VERBENACEÆ.

CŒLOCARPUM, *Balf. fil.*

Calyx tubuloso-campanulatus, membranaceus, 5-costatus costis in mucrones productis, fructifer patens cupularis drupaque brevior. Corollæ tubus cylindraceus, æqualis; limbus patens, 5-fidus, lobis oblongis obovatis obtusis parum inæqualibus, 2 posticis minoribus. Stamina 4, didynama, supra medium tubum affixa, inclusa, filamentis brevibus; antheræ cordiformes, inappendiculatæ, loculis divergentibus. Ovarium integrum, 4-loculare, loculis 1-ovulatis; stylus inclusus apice brevissime bifidus, lobo antico majore stigmatoso, postico erecto levi. Drupa succosa calyci patenti imposita, endocarpio osseo, pyrenis 2 2-locularibus lacuna intermedia separatis.

Semina exalbuminosa.—Frutex pubescens, inermis. Folia opposita, elliptica, crenata, venulis subtus prominentibus. Racemi terminales breves. Flores parvuli in axilla bracteæ minutæ breviter pedicellati, ebracteolati, secus rhachin alterni v. suboppositi, approximati.

Genus monotypicum *Citherexylo* Americano generi arcte affine.

145. C. SOCOTRANUM, *Balf. fil.*: species unica per montes Socotræ crescens. B.C.S. Nos. 299, 520.

146. CLERODENDRON (CYCLONEMA) GALEATUM, *Balf. fil.*: fruticosum fusco-tomentosum; foliis petiolatis ellipticis v. subobovatis; cymis strictis terminalibus; bracteis magnis foliaceis; corollæ lobo postico cucullato.

Nom. Vern. Dunha.

Socotra, in montibus Haghier prope Tamarida. B.C.S. No. 441.

147. CLERODENDRON LEUCOPHŒUM, *Balf. fil.*: arboreum cortice albo-tomentosum; foliis parvis oblongo-ellipticis; floribus solitariis axillaribus racemos longe pedunculatos formantibus; calyce subfructu patente; fructu cernuo.

Socotra, abundans. B.C.S. Nos. 182, 385.

LABIATÆ.

148. ORTHOSIPHON FERRUGINEUS, *Balf. fil.*: suffruticosus tomentoso-pubescens demum glaber; foliis longe petiolatis late ovatis v. subcordiformibus rarius obovatis obtusis crenatis utrinque puberulis ferrugineis; racemis 6–8-floris glandulosis; corollæ tubo calyce triplo-longiore, fauce nuda; staminibus corolla brevioribus.

Socotra, in montibus abundans. B.C.S. No. 420. Schweinf. No. 518.

149. LEUCAS (ORTHOLEUCAS) VIRGATA, *Balf. fil.*: suffruticosa virgata ramis fulvis; foliis petiolatis plus minusve obovatis v. spathulatis v. subellipticis integris v. superne trilobatis crassiusculis velutino-pubescentibus; verticellastris 3-floris; bracteis calyce multo-brevioribus; calycis dentibus brevissimis.

Socotra, frequens. B.C.S. Nos. 141, 274, 543, 548. Schweinf. No. 343.

150. LASIOCARYS SPICULIFOLIA, *Balf. fil.*: suffruticosa nana; foliis spiculiformibus v. triaculeatis; floribus solitariis axillaribus.

Socotra, in campis non frequens. B.C.S. No. 261.

151. LASIOCARYS FLAGELLIFERA, *Balf. fil.*: flagellifera; foliis spathulatis v. cochleariformibus cum dentibus 5–7 pungentibus; floribus solitariis axillaribus.

Socotra, inter rupes calcareas prope Galonsir crescens. B.C.S. No. 233.

152. TEUCRIUM (POLIUM) PROSTRATUM, *Balf. fil.*: prostratum ramis incanis; foliis petiolatis oblongis apice truncatis dentatis, basi abrupte contractis, revolutis; floribus in capitula pauciflora dispositis; corolla calyce pubescente duplolongiore.

Socotra, ad basim montium calcareorum prope Galonsir et Tamarida. B.C.S. Nos. 342, 547.

153. TEUCRIUM (POLIUM) PETIOLARE, *Balf. fil.*: perenne a collo ramosum ramis adscendentibus plus minusve incanis; foliis longe-petiolatis ellipticis, superne serrato-crenatis, inferne integris obtusis, parum revolutis, supra viridibus, subtus incanis; calycis dentibus deltoideis; corolla calycem pubescentem excedente.

Socotra, in montibus prope Galonsir. B.C.S. No. 431. Schweinf. No. 566, 578.

AMARANTACEÆ.

154. ÆRUA REVOLUTA, *Balf. fil.*: suffruticosa incana parva ramis erectis complanatis; foliis obovatis obtusis alternis revolutis subtus incanis supra demum glabrescentibus; spicis oblongis brevibus ad extremitates ramorum spicatim dispositis; floribus haud nitidis; perianthii segmentis uninerviis bracteolis multo longioribus; staminodiis brevissimis deltoideis.

Nom. Vern. 'Feh.

Socotra, in montibus Haghier. B.C.S. No. 478. Schweinf. No. 558.

THYMELÆACEÆ.

155. LASIOSIPHON SOCOTRANUS, *Balf. fil.*: fruticosus glaber; foliis obovatis v. oblanceolatis glaucis; bracteis involucri coriaceis glabris latis; calycis fauce esquamato.

Nom. Vern. Lēgief.

Socotra, frequens. B.C.S. No. 518. Schweinf. No. 567.

SANTALACEÆ.

156. OSYRIS PENDULA, *Balf. fil.*: arborea glabra ramis pendulis; foliis breviter petiolatis alternis lanceolatis v. suboblanceolatis acutis glaucis; floribus dioicis; ♂ dimorphicis in cymas 3–4-floras longe pedunculatas dispositis, plurimis minutis perianthio rotato 3–4-lobato discoque carnoso, paucis majoribus pyriformibus lobis conniventibus; ♀ ign.

Socotra, in montibus Haghier. B.C.S. No. 630.

EUPHORBIACEÆ.

157. EUPHORBIA (EREMOPHYTON) SOCOTRANA, *Balf. fil.*: arborea glabra; foliis magnis breviter petiolatis late obovatis apiculatis; capitulis magnis solitariis terminalibus; involucro glabro, bracteis fimbriatis; glandulis 6; staminibus paucis; capsulis seminibusque pulverulentibus.

Socotra, in montibus convallibusque. B.C.S. No. 464. Schweinf. No. 531.

158. EUPHORBIA (TIRUCALLI) OBCORDATA, *Balf. fil.*: fruticosa ramis juvenilibus puberulis; foliis breviter petiolatis late obovatis v. obcordatis crassiusculis; cymis solitariis terminalibus 3-cephalis; involucro extus pubescente, bracteis fimbriatis, glandulis rubris; staminibus paucis.

Socotra, in montibus. B.C.S. No. 268.

159. EUPHORBIA (TIRUCALLI) OBLANCEOLATA, *Balf. fil.*: suffruticosa ramis glabris; foliis subsessilibus oblanceolatis mucronulatis; umbellis cymosis terminalibus ramulis brevibus, bracteis magnis rotundatis; involucro extus glabro intus villoso, bracteis fimbriatis, glandulis flavis; capsulis glabris; seminibus tuberculatis.

Socotra, in montibus Haghier. B.C.S. No. 639.

160. EUPHORBIA (TIRUCALLI) ARBUSCULA, *Balf. fil.*: arborea

carnosa aphylla; cymis terminalibus sessilibus; involucri glandulis 5 concavis substipitatis; capsulis tomentosis; seminibus levibus carunculatis.

Socotra, abundans. B.C.S. No. 207. Schweinf. Nos. 241, 525.

161. PHYLLANTHUS (EUPHYLLANTHUS) FILIPES, *Balf. fil.*: suffruticosus ramis distichophyllis florigeris angulatis apicalibus; foliis oblongis, stipulis scariosis basi nonproductis; floribus monoicis paucis fasciculatis; staminibus 5, filamentis ad medium connatis, autherarum loculis contiguis; stylis 6; capsulis glabris trisulcatis longe filiformiter pedicellatis; seminibus scrobiculatis.

Socotra, in campis rarus. B.C.S. No. 332. Schweinf. No. 615 B.

162. JATROPHA (ADENOROPIUM) UNICOSTATA, *Balf. fil.*: arbuscula resinifera; foliis lanceolatis v. oblanceolatis glaucis unicostatis; stipulis minutis glandulosis; floribus majusculis; staminibus 8; capsulis magnis glabris.

Nom. Vern. Sibrha.

Socotra, frequens. B.C.S. Nos. 13, 89, 137. Schweinf. Nos. 256, 378. Perry.

163. CROTON (ELUTERIA) SAROCARPUS, *Balf. fil.*: arbor; foliis ovatis penniveniis longe petiolatis lamina basi patellari-glandulosa subtus argenteo-lepidota; stipulis subulatis; inflorescentiis pseudo-terminalibus; floribus dioicis; ♂ racemis multifloris, alabastris globosis, staminibus ultra 20; ♀ umbellis paucifloris, stylo bis bifido, capsula dense setigera, seminibus levibus.

Socotra, in montibus. B.C.S. Nos. 298, 318, 640. Schweinf. Nos. 517, 666.

164. CROTON (ELUTERIA) SULCIFRUCTUS, *Balf. fil.*: fruticosus; foliis ovatis penniveniis petiolatis lamina basi patellari-glandulosa subtus argenteo-lepidota; stipulis subulatis; glomeruli florium in spicas dispositi; fl. ♂ supremi subsessiles, staminibus sub 20; fl. ♀ pauciores basales pedicellati, stylo bis bifido, capsula 6-sulcata lepidota lepidibus planis, seminibus levibus.

Socotra, in montibus Haghier ad alt. supra 2500 ped. B.C.S. Nos. 484, 496. Schweinf. No. 621.

165. CROTON (ELUTERIA) ELŒAGNOIDES, *Balf. fil.*: arboreus; foliis auguste ovatis penniveniis longe petiolatis lamina basi patellari-glandulosa subtus metallico-lepidota; stipulis inconspicuis: fl. ♂ ignotis; fl. ♀ in umbellas dispositi, stylo bifido, capsula lepidibus umbonatis dense vestita.

Socotra, in montibus Haghier infrequens. B.C.S. No. 492.

166. CROTON (ELUTERIA) SOCOTRANUS, *Balf. fil.*: fruticosus; foliis penniveniis petiolatis bidentibus ab parvis ellipticis v. obovatis ad formas oblongas ovatas variantibus lamina basi patellari-glandulosa, pagina utraque pilis stellatis sparsim vestita; stipulis obsoletis; floribus pedicellatis in umbellas unisexuales terminales dispositis; staminibus ultra 20; fœminei floris petalis linearibus; stylo bis bifido; capsula dense pilis setosis penicillatis vestitas; seminibus levibus.

Socotra, frequens. B.C.S. Nos. 1, 278, 494. Schweinf. Nos. 449, 798.

167. CEPHALOCROTON SOCOTRANUS, *Balf. fil.*: fructicosus; foliis ad extremitates ramulorum lateralium contractorum sæpe fasciculatis rotundatis v. obovatis subintegris penniveniis; fl. ♀ sepalis integris.

Nom. Vern. Than v. Tehn.

Socotra, in montibus altissimis et in campis maritimis. B.C.S. Nos. 391, 633. Schweinf. Nos. 430, 544, 797.

168. TRAGIA (TAGIRA) DIOICA, *Balf. fil.*: volubilis lignosa urens; foliis oblongo cordatis grosse dentatis pilosis et hispidis: floribus dioicis; ♂ 3-meris; ♀ calyce 5-lobato, lobis palmatim 5-fidis subfructu ampliatis et induratis, laciniis linearibus hispidis; ovario hispido; stylo fere ad basin trifido, segmentis revolutis.

Socotra, per montes abundans. B.C.S. Nos. 366, 626. Schweinf. Nos. 360, 479.

URTICACEÆ.

169. DORSTENIA GIGAS, *Schweinf.*: caulescens caudice crassissimo carnoso ramoso; foliis oblanceolatis bullatis; receptaculo orbiculari margine 6-8-radiato.

Socotra, inter rupes ad montes. B.C.S. No. 638. Schweinf. 737.

170. Ficus (Urostigma) socotrana, *Balf. fil.*: arborea ramulis pubescentibus; foliis rotundato-cordatis molliter pubescentibus 5-nerviis utrinque alterne 5-8-costatis; stipulis villosis; hypanthodiis obovatis pubescentibus; achæniis ovoideis levibus perianthio membranaceo inclusis.

Nom. Vern. Tuk.

Socotra, abundans. B.C.S. No. 283. Schweinf. No. 414.

ORCHIDEÆ.

171. Habenaria socotrana, *Balf. fil.*: glabra caule gracili; foliis membranaceis oblanceolatis v. oblongis; racemis elongatis floribus distantibus; bracteis ovario brevioribus attenuato-acuminatis; sepalis petalisque obtusis; labello 3-partito lobis linearibus calcare gracillimo ovario longiore.

Socotra, in montibus prope Galonsir. B.C.S. No. 315.

DIOSCOREACEÆ.

172. Dioscorea lanata, *Balf. fil*: volubilis caule tereti piloso; foliis cordatis v. rotundatis v. reniformibus apice spinoso-mucronatis 7-9-nerviis subtus lanatis; spicis solitariis axillaribus; fl. ♂ glomeratis, staminibus 6, ovarii rudimento depresso triquetro; fl. ♀ solitariis, capsulis pubescentibus.

Socotra, in montibus Haghier. B.C.S. No. 482. Nimmo.

AMARYLLIDEÆ.

173. Hæmanthus grandifolius, *Balf. fil.*: glaber et immaculatus; foliis magnis sæpe 1¼ ped. longis ¾ ped. latis ovatis v. elliptico-ovatis acutis basi parum attenuatis v. plerumque rotundatis v. rotundato-cordatis margine vix undulatis tenuibus delicate venulosis, petiolo 1–1½ poll. longo non vaginante.

Socotra, in montibus Haghier prope Tamarida. B.C.S. No. 194.

LILIACEÆ.

174. **Aloe (Eualoe) squarrosa**, *Baker* : caulescens caudice simplex; foliis parvis laxe dispositis lanceolatis patulis maculatis apice recurvatis aculeis marginalibus magnis crebris deltoideis; scapo brevi simplici ancipiti; racemo simplici cernuo; pedicellis brevibus ascendentibus bracteis lanceolatis; perianthii cylindrici tubo brevi; staminibus inclusis; stylo exserto; capsula parva.

Socotra, in montibus calcareis prope Galonsir infrequens. B.C.S No. 282.

GRAMINEÆ.

175. **Eriochloa vestita**, *Balf. fil.* : omnino molliter pubescens rigide ramosa; foliis crassiusculis rigidis brevibus; racemis paniculi 6–8, spiculis compressis ovoideis; glumis vacuis villosis pungentibus, glumis fertilibus muticis.

Socotra, in campis calcareis prope Galonsir. B.C.S. N. 574.

176. **Panicum rigidum**, *Balf. fil.* : cæspitosum ramis decumbentibus radicantibus ad nodos villosis; foliis brevibus rigidis ad apicem vaginæ villosis; paniculis laxis ramis ramosis plerumque glabris, spiculis omnibus pedicellatis; gluma extima brevissima, glumis interioribus 2 subæqualibus 5-nerviis glabris obtusis, gluma florali levi obtusa.

Socotra, prope Galonsir et Tamarida. B.C.S. Nos. 130, 561. Schweinf. No. 346.

177. **Rhynchelytrum microstachyum**, *Balf. fil.* : vix pedale plus minusve puberulum tenue; paniculi parvi spiculis $\frac{1}{5}$ poll. longis; glumis secundis et florentibus tertiis apice bifidis lobis rotundatis, aristis glumis vix excedentibus.

Socotra, apud Galonsir et Tamarida. B.C.S. Nos. 124, 254. Schweinf. No. 467.

178. **Lepturus tenuis**, *Balf. fil.* : cæspitosus breviter repens tenuis; foliis angustis linearibus glaucis longis piloso-puberulis; spicis compressis; gluma vacua solitaria plurinervia florenti gluma et palea duplolongiore; stipite glumam minutam hyalinam gerente.

Socotra, in campis orientalibus insulæ. B.C.S. No. 572.

ISCHNURUS, *Balf. fil.*

Spiculæ 1-floræ in spica simplici ad excavationes rhacheos compressæ solitariæ, alternæ, sessiles, rhachilla brevissima supra glumam inferiorem articulata ultra florem in stipitem brevem plerumque florem imperfectum gerentem producta, flore hermaphrodito. Gluma infima vacua, rhachi opposita, brevis, rigida, oblonga, truncata v. obtusa, basi incrassata tumida, 8-nervia, margine membranacea; florens æquilonga, membranacea, trinervia, apice obscure trifida ciliata; palea æquilonga, membranacea, 2-nervia. Stamina 3. Styli breves, distincti, stigmatibus plumosis. Caryopsis late ellipsoidea, compressa, glabra, gluma paleaque inclusa, libera.—Gramen perenne, nanum v. elatum, cæspitosum, multicaule, foliis glaucis pilosis. Spica terminalis, rigida, tenuis, recta, spiculis parvis dissitis in rhachi alte excavata quasi inclusis, gluma infima vacua semper adpressa.

Genus monotypicum novum Hordeearum bene distinctum sed *Oropetio* et forsan *Lepturo* affine.

179. I. PULCHELLUS, *Balf. fil.*: species unica in locis arenosis apud Galonsir crescens. B.C.S. Nos. 109, 301.

Monday, 5th February 1883.

PROFESSOR JENKIN, F.R.S., Vice-President,
in the Chair.

The following Communications were read:—

1. On Scientific Method in the Study of Language.
By *Emeritus* Professor Blackie.

2. Further Remarks on the Mirage Problem. By
Professor Tait.

BUSINESS.

The following candidates were balloted for, and declared duly elected Fellows of the Society:—The Hon. Lord Kinnear; Mr W. Bowman; and Mr R. H. B. Wickham.

Monday, 19*th February* 1883.

SHERIFF FORBES IRVINE in the Chair.

The following Communications were read:—

1. On Ancient Tenure of Land in Scotland.

By Mr Auldjo Jamieson.

I deem no apology due for introducing to the notice of the Royal Society the subject of the present paper. The close and accurate criticism which distinguishes modern scholarship has allied all branches of knowledge in a common scientific system; and the laws which regulate the development of human society are now recognised as being not less inexorable than those of which the operation on material objects is the more frequent theme in this room. To exhume the forms and types of ancient society, to subject them to close analysis, to identify their prototypes and trace their evolution in our modern life is not less a scientific study than to dig out the nodules of remote ages from those ancient records the rocks, and to subject them to that analysis which detects their identity with forms of life still extant. But with this difference in our present inquiry: the forms of existence of which the nodule is the representative have transmitted their characteristics through so great a succession and variety of forms as to make their identity with, or even relation to, any modern type distinguishable in most cases only by subtle processes of analysis; they are themselves callous and dead, and have no direct contact with the life of the present day; but the systems of ancient society have not undergone that process of extinction and disintegration in transmitting their characteristics; it is less in the alembic that decomposes than by the scalpel that exposes, that their characteristics are discoverable; they do touch, and that often closely, the living present, and there is danger therefore that in the search for ancient truth a nerve may be sometimes touched that may send a thrill into living organisms in our modern society, aflame as some of these are at present with fevered sensation and debate.

I must disclaim at the outset all pretence to originality in either my investigations or their results; my object and purpose will be to present in a brief and conventional form some of the more salient results which recent scientific investigation has reached as to the relations in which men have stood with reference to the soil of this land in the earliest days of which we have a record, and to trace back to these pristine forms such of the main characteristics of our modern land system as derive their origin therefrom. The study of such subjects has of late progressed so rapidly, and the light thrown on the dark records of the distant past by the patient labours and skilful investigation of such scholars as Dr Skene, Sir H. Maine, and others, has been so clear and so searching that the time seems to have come at which it may be fitting for a mere disciple to enter on the task—not perhaps altogether inappropriate to one brought often into practical contact with existing phenomena of the nature we are to consider—of identifying those characteristics of human experience in this relation of life which in the long evolution of society have stood the test of survival as the fittest for the later development of human life.

The task I thus undertake would necessitate at its outset an ethnological sketch of our Scottish land as we now know it; but I will leap over many perplexing difficulties by assuming a general assent to the view that when the curtain rises on its modern history Scotland was thus peopled,—the Lothians, Fife, Forfar, and Aberdeen, with a population almost wholly Saxon; Sutherland and Caithness with a race also Saxon, but largely Danish and Norwegian; and all the rest of Scotland Gaelic, saturated in Galloway with Saxon or Frisian influences, and characterised in the same district by traces of a more ancient race; with fringes of Irish Gaels on the coasts of Argyll and of Danes and Norwegians in the Isles.

I suppose the rough view which most men who thought on the subject at all had, until a comparatively recent period, formed of the growth of society, was its development from a family into the patriarchal form, and then a number of patriarchs combining with their respective families to form a community, a country, or a state. But nothing in this inquiry is now more clearly determined than that the unit of primitive society, and the centre of all archaic land systems was not the family, but the tribe. The family as we know it was a comparatively late creation, and I think we may doubt whether it had any definite place among our own forbears until Christianity lent its sanction to the domestic relations. Community of wives unquestionably characterised that system out of which the Gaelic and the Saxon alike proceeded, and contemporaneous therewith was the community of land which was unquestionably the first form of tenure, if that can be called tenure which nobody held. The earliest traces that exist of social life in the past, and all the analogies that scientific investigation has discovered in the more modern types of archaic society which survive, point irresistibly to the conclusion that while individual rights existed and were recognised in personal property, the soil was regarded and treated as the common property of the tribe; and naturally so, while as yet man sought his scanty subsistence in the chase and in the waters, and the untamed earth yielded to him in common with the beasts he hunted only the spontaneous tribute of its wild berries and roots. While it would be affectation to assert anything definite of a state of society which has left behind it so few traces, and these necessarily so indefinite, still one can discern the first germ of right and title in land in the right which the tribe itself naturally came to assert as against other tribes in the region within which it first began to settle; the choice corries of the deer, the favourite pools of the salmon, above all, the dwellings of their dead, would begin to possess an individual value to that tribe which first began to haunt these localities, and other tribes would be taught to reverence what the one tribe had begun to value; and this was probably the dawn of land right and land tenure.

The tribe first emerges with us from the darkness of barbarism at that epoch of its existence when restrained and coerced by the growth of population the nomadic habits of the race began to give place to pastoral life, and man began to assert his supremacy over the brute creation otherwise than by hunting them. When first the tribe or its individual components began to feed cattle the necessity of feeding ground made itself felt, and it is just at that point that economic history really begins; there is no trace of which I am aware of a common estate in cattle. On the contrary everything tends to the conclusion that among the early inhabitants of this land cattle was the form of property over which the individual rights of man was first asserted, and cattle became the measure in and by which other rights and property were appreciated. Cattle was the money of the ancient people with whom we are now dealing, and was at the same time the measure and token as well as the substance of their wealth.

It is in Ireland that we must seek both the origin of our Gaelic tenure and the only reliable records of its early growth, while the original features of our Saxon system must be sought in the records that survive of the systems of our German ancestry. One important element in differentiating the Gaelic and the Saxon systems was the earlier Christianity of the Irish and Scottish Gaels, an element—that early Gaelic Christianity of ours—so thoroughly distinctive and so full of special influence, which has left deeper and more frequent traces on our national character and habits than those who distinguish only the catastrophes that signalise abrupt revolution can recognise or are likely to acknowledge.

Giving therefore its due precedence to the more ancient system, the land which the Gaelic tribe held when first we can throw any real light upon it had ceased to be the mere grazing ground of the cattle: agriculture of a rude type had begun to be practised, and the land over which the tribe asserted its sway was of four classes—the land appropriated to the dwelling and its immediate surroundings, the land appropriated to cultivation, the land appropriated to pasture, and the land left free for the chase or otherwise unappropriated. This is the pristine and rudimentary form of land tenure and of society based thereon, which must be accepted as the uniform and invariable type which has prevailed over every part of the world in which man has risen above the level of the savage. Not only in Aryan communities of every variety and of all circumstances, but in communities of Mongolian, African, and Polynesian descent. Modified it was of course by climate, and by soil, and by the innate habits of the people; but wherever men have begun to assert their supremacy over the earth and its products we find these four distinct stages of tenure:—first, the homestead with its yard, the only private or separate property of the tribesman; second, the cultivated zone round the aggregated homesteads, the "field" of the robust inhabitant of temperate climes, or the garden of those more bounteous climates where vegetables more than grains are the food of the people; third, in races of a pastoral type the common pasture land; and lastly, in all, the waste or unappropriated—the hunting grounds perhaps—but always the magazine from which, as it grew, the tribe drew its supply of fresh land for its increasing numbers.

A very pleasing and simple picture of pristine society is thus presented, and one to which it would rather seem that there is an anxiety in some quarters to revert; it is well therefore to dispel delusions and to point out that this typical condition of ancient life existed with us only as an imaginary point from which to measure the advance to more developed systems. The influences which sway mankind now, swayed them in these olden times: the inexorable laws which operate now among the myriad incidents of our modern life operated then with the same force; and it is interesting to distinguish their operation where we can discern the immediate succession of cause and effect so clearly as we can in those simple communities, just as we can best discern the growth of the organs of riper life in the rudimentary forms they present in the lower types of creation.

What then are the influences to which the historian and the social economist attribute the growth and development of our race? Laying aside the influences of religion as operating in a different plane from that in which we are now moving in this inquiry, I apprehend physical energy and money, the active potentiality of brute strength, and the passive and accumulative force of labour and self-denial, of which wealth or money is the result and embodiment—are those forces which have operated and do operate most strongly on human action; the strong man and the rich man, the strong nation and the rich nation are those which dominate, and in our primitive society no sooner has the curtain risen on the simple pastoral scene I have briefly sketched, than the action of the drama begins by the strong man rushing in on the stage—the Saul of the tribe, lofty in stature and bold of heart, to claim the share of the common property due to his superior prowess—and we find the social equilibrium at once disturbed in order to find for this Kingly man his fitting tribute.

Therefore in the Celtic tenure the mensal lands of the king and the lands devoted to his special maintenance were the first to be cut out of the common property; the king had his own share of the lands as a member of the tribe, and he had the mensal lands besides to support his royal state. These mensal lands remained no doubt still vested in the tribe, and the king had but a user of them for his life or office. Then came the church, and another part of the tribal lands—the ternal—was set aside for it. But an influence more powerful, perhaps because more subtle than even the regal and the religious, operated to disturb the equilibrium—money began to exercise its sway: dealing with the Irish as the oldest type of the Gaelic tenure, we find the share of the annual allotment of land was regulated by the extent of the herd of each member of the tribe;* perfect equality even in these early days was a matter of theory, and was maintained not because men *were* equal, but only until the supremacy of the fittest had asserted itself according to the inviolable law of progress; and as personal property was undoubtedly separate and individual, the thrifty, the skilful, the industrious, would soon become the rich in cattle, and would soon come to have an increasing share of the common arable land, while the pasture was still common to all equally. Thence arose a very peculiar form of tenure; when one of the tribe became so rich as to have more cattle than he could find pasture for on his own allotment, he lent his surplus stock to less careful or less fortunate members of the tribe, who thus became his "*tenants.*"†

It is very notable that in this, which we must accept as the most pristine form of the relation between landlord and tenant, the landlord was *required* to contribute the stock as the essential element in the transaction, and the rent was paid not for the land but for the stock; it is evident that the idea of a separate personal possession of the land was very imperfectly developed at that stage in the history of the tribe at which the power of money first began to effect a differentiation between the members of the tribe, and we have the germ presented to us of the relation now so familiar of landlord and tenant.

But this rudimentary differentiation which we recognise in the Irish tribe rapidly grew, and it developed into one of the worst and most fatal, but still essential, characteristics of all early tenures and of all early society; if it contained within it the germ of the landlord and tenant of later days, it contained a germ of more dangerous import to, and more immediate influence on, infant communities.

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* Skene's *Celtic Scotland*, vol. iii. p. 142.

† *Idem*, p. 147.

When the richer man contributed only a portion of the stock to a freeman of the tribe who already possessed some of his own, that poorer freeman had to return a third of the value of the stock annually for a specific period; but when the freeman had no stock of his own, he had to give security for the return of the stock lent, and to pay a food tribute, the type and evidence of vassalage, twice a year. The former, the "Saer Ceile," were the antetypes and progenitors of the vassals of later times; and the latter, the "Daer Ceile" or bond tenants, were the antetypes and ancestors of the serfs and servile races, from whom the charity of the church and the chivalry it begot in long years after, and with many a painful effort, struck the shackles of slavery. Dr Skene says:—"With the Saer Ceile the basis was a mutual contract for a fixed period, usually of seven years, by which the chief gave a portion of stock proportionate to the food-rent he was to receive in return, and was entitled along with this to the homage of the tenant during the subsistence of the contract, and to a certain amount of service in the erection of a dun or fort, the reaping of his harvest, and the sluaged or hosting; but the contract would be terminated and the parties to it return to their original relation to each other, either by the tenant returning the stock he had received or the chief reclaiming it. A more permanent connection was formed between him and the daor ceile or bond tenant. Here the ceile placed himself formally under the protection of the chief as his permanent follower by receiving a certain number of seds or cows, by way of subsidy or gift from the superior, and paying him a certain tribute as the price of his protection. As soon as this relation was constituted he received an additional amount of stock in proportion to the food-rent he had to return, in the same manner as in the case of the free ceile. The real distinction probably was, that in the one case the ceile was in a more independent position, and possessed stock of his own as well as a share of the tribe land, besides what he received from the chief. In the other he was dependent upon what he received from the chief for the whole of his stock. When the chief reclaimed his stock from the free ceile, the latter had the option of becoming a bond ceile if he preferred doing so to returning his stock, and the chief was then bound to add the returnable seds to the stock he had originally given, which constituted the relation between him and the ceile as a permanent dependant. This process, therefore, not only led to the freemen of the tribe being gradually absorbed into the class of the dependants or following of the chief, but placed a powerful weapon in the hands of the latter, by which he could transform his temporary free ceile into permanent and more servile dependants." *

The separate ownership of land by inheritance seems to have resulted in the Celtic tribes at first from a tacit prescription, the precise origin and foundation of which it would be very difficult to determine. The firm hold which from the first each member of the tribe evidently had on his homestead gave to the skilful breeder or the careful tender of his herd a fulcrum no doubt on which he could work the lever of his wealth; and when for three generations a family retained possession of land, that possession became the basis of title and of a right transmissible by the holder to the succeeding members of his family;† thus originated, it would seem almost by accident or intuitively the right of separate perpetual tenure, on which was raised the superior class of territorial magnates—the original chieftains of the septs and clans into which in its later development in Scotland, preparatory to its final extinction, the tribe broke up.

And when that time for its extinction came, when Alexander III. died in 1286, and the fresher, freer, nobler influences of Saxon and Norman life stirred the stagnant system of Celtic society and gave life and vigour to our Scottish institutions, the form which the tribe had assumed in Scotland was this; there was the central figure, the thane, possessing a large part of the lands as his demesne, representing the mensal lands of earlier days, and very large rights of superiority and service from the inferior members of the tribe; over these thanes there held rule more or less defined, and originating in circumstances exterior to the tribal organisation, the earls of the seven provinces, but that rule was less, I apprehend, a matter of land tenure than of personal rule; below the thanes came a class which can best be described as freeholders holding their lands in absolute fee, but bound as the condition of their tenure to give personal service and to pay certain definite and elaborately regulated duties; below them again came a class of free or kindly tenants,

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* Skene's *Celtic Scotland*, vol. iii. pp. 172, 173.

† *Idem*, p. 144.

"liberi et generosi," who held portions of land for ten or twenty years, or for life, with remainder to one or two heirs; these were the representatives of the Ceile of the Irish system, for in many cases the landlord provided the stock and implements, and the rent paid was higher in proportion to the value of these steelbow goods, the rent of the land itself being probably a fixed quantity. With these ended the grades of free tenure, but below these came two grades very important to us as interesting historical types:—*first*, the agricolæ or rustici, who held land from year to year on payment of a fixed rent, but were from their tenure of those servile lands themselves serfs; and *second*, another class of serfs by whose forced labour the chief or thane cultivated his demesne, and who were in the strictest sense slaves. All ancient systems of society and of tenure are tainted by this bane of slavery, but the Celtic system seems to have been saturated with it, and it is a lurid light which these two classes of serfdom throw on the expiring system of our Celtic land tenure, a light which, before I conclude, I will seek to throw into some regions where I humbly think its illumination may be salutary.

The whole framework of this Celtic tenure, with all its intricate arrangements of the clans and septs presenting an elaborate system of order and gradation, conforms but little with our notions of the freedom and breadth of the childhood of our race. The Eastern influence in the Celtic church is unquestionable, and the church exercised a paramount influence in forming the infant society of the Celtic race; the same hard and inexorable rule, the same elaborate gradation, the same spirit of exclusiveness, and the same family pride which characterised the Celtic church as it expired before the more vigorous system of the Roman obedience characterised the Celtic tribal development as it too passed from the stage of history. Was it from the unchanging East, that weird museum in which even now the worn out theories of human society seem preserved for our modern study, that the seeds of the disintegration as well as the germs of the development of Celtic society came?

The records of Saxon tenure, if in some respects less interesting than those of Celtic holding, are at least less obscure and indistinct; and the labours of Freeman, Maine, and German inquirers, whose researches have been summarised with skill in an admirable paper by Mr Morier,* have thrown a vast deal of light on this subject. It is, however, at a comparatively late period of its development that the Saxon tenure can have had much influence on our Scotch land, at a period too when the orderly influences of the Western church had modified considerably its original character, and had prepared it to receive with ready plasticity the more sharply defined features of the Norman mould. The unit of the Saxon system was the "mark," which in analogy with Celtic and other Archaic systems may be described as the heritage of the tribe. Just as in the Celtic tenure part of this mark was held jointly by the whole community as common pasturage or woodland; another section was divided into lots tilled by separate members of the community, but strictly according to fixed rule, and thrown open to common use so soon as the crop was removed; a third section was divided into small paddocks or holdings immediately adjoining the township. There seems to have been from very early times separate ownership in these last enclosures, and a separate ownership also in the tillage lands qualified by the common use of them for pasture after harvest.

This system has often been referred to as containing the germ of that co-operative system of cultivation that commends itself to many in the present day as the most advantageous. It is perhaps somewhat fortunate that there have remained until a comparatively recent period traces of this system in both England and Scotland, which enable us to appreciate its real effects, and to discern its appropriateness or the reverse to our modern life. One of the most graphic instances of that survival we have thus recorded:—

"The two large pieces of common land called Dolemoors, which lie in the parishes of Congresbury, Week, St Lawrence, and Puxton in Wiltshire, were allotted in the following manner. On the Saturday preceding Midsummer day, o.s., the several proprietors (of the estates having any right in these moors) or their tenants were summoned at a certain hour in the morning, by the ringing of one of the bells at Puxton, to repair to the church in order to see the chain (kept for the purpose of laying out Dolemoors) measured. The proper length of such chain was ascertained by placing one end thereof at the foot of the arch, dividing the chancel from the body of the church, and extending it through the middle aisle, to the foot of the arch of the west door under the tower, at each of which places marks were cut in the stones for that purpose. The chain used for this purpose was only eighteen yards in length, consequently four yards shorter than the regular land-measuring chain. After the chain had been properly measured, the parties repaired to the commons. Twenty-four apples were previously prepared, bearing the following marks, viz., five marks called 'Pole-axes,' four ditto 'Crosses,' two ditto 'Dung-forks, or Dung-pikes,' one mark called 'Four Oxen and a Mare,' one ditto 'Two Pits,' one ditto 'Three Pits,' one ditto 'Four Pits,' one ditto 'Five Pits,' one ditto 'Seven Pits,' one 'Horn,' one 'Hare's-tail,' one 'Duck's-nest,' one 'Oven,' one 'Shell,' one '*Evil*,' and one 'Hand-reel.'

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* *Systems of Land Tenure*, Cassell, 1870, p. 297.

"It is necessary to observe that each of these moors was divided into several portions called furlongs, which were marked out by strong oak posts placed at regular distances from each other, which posts were constantly kept up. After the apples were properly prepared they were put into a hat or bag, and certain persons fixed on for the purpose began to measure with the chain before-mentioned, and proceeded till they had measured off one acre of ground; at the end of which the boy who carried the hat or bag containing the marks took out one of the apples, and the mark which such apple bore was immediately cut in the turf with a large knife kept for that purpose; this knife was somewhat in the shape of a scimitar with its edge reversed. In this manner they proceeded till the whole of the commons were laid out, and each proprietor knowing the mark and furlong which belonged to his estate, he took possession of his allotment or allotments accordingly, for the ensuing year. An adjournment then took place to the house of one of the overseers, where a certain number of acres reserved for the purpose of paying expenses, and called the 'out-let' or 'out-drift' were let by inch of candle.

"During the time of letting, the whole party were to keep silence (except the person who bid) under the penalty of one shilling. When any one wished to bid he named the price he would give and immediately deposited a shilling on the table where the candle stood, the next who bid also named his price and deposited his shilling in like manner, and the person who first bid was then to take up his shilling. The business of letting thus proceeded till the candle was burnt out, and the last bidder, prior to that event, was declared the tenant of the outlet, or outdrift for the ensuing year.

"Two overseers were annually elected from the proprietors or their tenants. A quantity of strong ale or brown-stout was allowed for the feast, or 'revel,' as it was called; also bread, butter, and cheese, together with pipes and tobacco, of which any reputable person, whose curiosity or casual business led him to Puxton on that day, was at liberty to partake, but he was expected to deposit at his departure one shilling with the overseer by way of forfeit for his intrusion. The day was generally spent in sociality and mirth, frequently of a boisterous nature, from the exhilarating effects of the brown-stout before alluded to."*

But we have, as is well known, in our immediate vicinity in the burgh of Lauder and at Newton of Ayr equally interesting survivals; —that of Lauder especially, where 105 burgess lots are held under a charter of 1502 renewing more ancient charters which had perished, and conferring power on the burgesses and community to break up and plough their common lands. The possession of one of these burgess acres or lots is essential to being a burgess, and only burgesses are members of the Town Council. The burgess acres consist of lots of from one and a half to three and a half acres, but the burgh holds besides a common of 1700 acres, which is thus dealt with. Once in every five or seven years about 130 acres of the common is set off to be ploughed up and cultivated; the part thus broken up is divided into 105 lots, and each owner of a burgess acre is entitled to a lot which is determined by lot. On the rest of the moor such of the 105 burgesses as are residents pasture each fifteen sheep and two cows, and the widow of a burgess pastures twelve sheep and one cow. Here then we have the Lauder burgess with his "homestead" in Lauder, his share of the "arable mark" in his acres, and his share of the "pasture" and "waste" in the moor; and we have the Council of Lauder prescribing to each burgess the kind of cultivation he is to pursue on the lot of the common land assigned to him. Somewhat similar tenures prevailed in Newton of Ayr,† in Crawford in Dumfriesshire,‡ where even more primitive rules prevail, and Whitsome in Berwickshire;[*] and the system of cultivation which this tenure prescribed—by which the holder of each lot had to conform to the general directions of the community—prevailed widely in the run rig system which was so largely the rule a hundred years ago. The parish of Smailholm was all cultivated in that manner, and at Libberton in Lanarkshire, and many other places, this system of agriculture, testifying manifestly to the prior existence of some quasi-communal cultivation, may be distinctly identified.[†]

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* Hone's *Book of Days*, vol. ii. p. 918.

† *Statistical Account of Scotland*, vol. ii. p. 263.

‡ *Idem*, vol. iv. p. 512.

And there are some other traces of a regulation which reflects much light on the real nature of this tenure. At Newton of Ayr there were very special provisions as to the succession to a burgess; and it not unfrequently happened that as females were excluded, a lot lapsed by the failure of an heir qualified to take it up; it then reverted *to the Community*, which disposed of it to the most industrious and fit inhabitant of the place. This, if it could be traced in other cases, would be most interesting, for it would connect this old Saxon tenure of ours very closely with its pristine origin in the distant past in the very cradle of mankind—showing as it does that the tribe or commune was still the radical owner of the soil, and the tenure of individuals only accidental—and connecting this tenure of the Lowland village with those tenures of Eastern and some German types where the right of pre-emption is reserved to the community or its members, and with that provision we are all familiar with, whereby at stated periods of jubilee the tribe reclaimed its lost inheritance from private ownership, and the members of the tribe started afresh on a fresh lease from their mother tribe.[‡]

In the rapid and necessarily very incomplete sketch which I have thus given of the early tenures in this country there are some notable features which challenge observation in these days. The first of course is the trite but by no means unchallenged observation that the very origin and germ of progress and civilisation is the recognition of individual right. Mankind in the mass remained inert and indolent in the dim twilight of the earliest days: it was man that rose to vigour and action and progress when he asserted his individualism, and when the leaders of men, spurning the dead level of uniform stolidity, became the pioneers for their fellow-men. No progress—no attempt at progress—is discernible during the dim ages when the land owned no separate title; it was only when what for lack of a better word I must call selfishness contributed its ferment to the inert mass of humanity that the individual sporades developed that activity which we call progress, and of which the product is civilisation.

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[*] *New Statistical Account*, vol. ii., *sub voce.*

[†] *Statistical Account*, vol. iii. p. 217, vol. ii. pp. 98 and 242.

[‡] *New Statistical Account*, *sub voce.* See also Fenton's *Early Hebrew Life*, pp. 71–73.

The second observation flows out of the first: the cultivation of the soil, though the oldest of the arts, is still an art itself of which the basis is experience and the spirit is experiment. Even with ourselves those who are the most proficient in the art desire to free our agriculture from the trammels which seem to them to repress and restrain its still nascent capacity; the freedom of culture desired by many is justified on the ground that successful experiment may reveal fresh methods and more adequate modes of culture. But under any conceivable modification of the Saxon tenure progress was impossible, because experiment was impossible and change impracticable. The same uniform rule of culture had to be followed in even the separate tillage lots because all were interested in the common cultivation; every one had to sow the same crop and to cultivate it in the same way, and the fields had to be cleared for the common pasture on the same day; much of the sluggishness of English agriculture may be distinctly traced to the surviving influences of that Saxon tenure which imposed those fetters of iron custom on the cultivation of the soil from which hardly yet have English agriculturalists emancipated themselves. In Scotland the Board of Agriculture in 1798 say:—"In former times there were several commons in which the cattle belonging to different proprictors went promiscuously under one herd or keeper. The arable land also was possessed in alternate ridges, separated by broad balks, on which the large stones were when the indolent husbandman could take that trouble, and was pastured by the cattle after being freed from the crops. Lands thus awkwardly possessed and wretchedly managed, might not improperly be called wastes; and though Acts of Parliament passed as early as 1695, for dividing at the instance of any proprietor having interest, yet no advantage was taken of such beneficial laws till the 1738 or 1739, when the lands were parcelled out among the several proprietors in proportion to the valuation or rate by which they paid the land tax."[*] Nor where Celtic customs prevailed can we discern any greater evidence of progress: we have few traces of how the Highlands were cultivated in very ancient times, but when we first begin to acquire definite knowledge there is much to show that the effect of the ancient tenures had been to arrest rather than promote active and beneficial cultivation of the soil.[†] Time will not permit of my adducing detailed evidence of this—let me call one witness, no unfriendly one, to the past he reverenced or to the Highlands he loved. Cosmo Innes says, speaking of the rental in 1600 of the Gordon estates, which extended from Banff through the heart of the country to the western sea:—"In all that vast estate reaching from sea to sea, and across ranges of mountains now everywhere pastured by sheep and cattle, there is no payment of wool or woollen cloth, nor of hides or skins, nor any amount of sheep and cattle beyond the occasional mart or wedder for the lord's table. In fact there were at that time no cattle or sheep reared in large flocks and herds in our Highlands. The space and pasture were the same as we know them now, but the thousands and millions of sheep which graze them now had not yet taken possession. The first introduction of large flocks of sheep into the Highlands was in the last quarter of last century. Gough the antiquary, writing in 1780, says that Mr Loch's plans for introducing sheep had been 'attended with some success,' and that the sheep promised to thrive very well in the Highlands. But at this time (1600) there were nothing but the petty flock of sheep or herd of a few milk cows grazed close round the farmhouse, and folded nightly for fear of the wolf or more cunning depredators."[‡]

The third observation I would make is this, that the admiration and affection for these ancient tenures professed of late appears to be based on the idea that they were of a highly democratic and universalist type; there can be no greater mistake; whether we take the Celtic sept and clan or tribe, or look at the Saxon community with its mark and its gemote, we find a system of rigid exclusiveness, an aristocracy in tenure, an oligarchy in government. There was originally no doubt a certain rude equality, but it was only "pares cum paribus," and the "peers" were few, the commons were the many. The Celtic tribe was an exclusive corporation to which birth within its own purple was as essential as it was at the Court of the Empire: the Saxon freeholder was an aristocrat of the bluest blood—no base intruder was permitted to share the privileges or the powers to which the freeholder alone was born—it was oligarchy saturated with caste. The essay in which Mr. Freeman identifies the wittengemote, which has been to many the type of popular self-government by landowners of a common estate with the House of Lords, not the House of Commons, forcibly illustrates what I say; but the case of Lauder illustrates it in a startling though a more homely fashion. There there are 105 freemen, and they have successfully resisted the claims of the profane vulgar of that august city to participate in their privileges: one would regret that anything should happen to shatter so interesting a petrefaction and crystallisation of ancient tenure, but a tenure which maintains an exclusive right of 105 persons to appropriate the ancient common property of the "gemote" is not what I should designate as a peculiarly popular system; it is most interesting that these village aristocrats should share the arable mark and feed their fifteen sheep apiece on the common waste of Saxon tenure, as their fathers did in the time of the Maid of Norway; but though history would have lost a graphic illustration it would not seem to me that humanity would have suffered an irremediable loss had the common estate of Lauder assimilated itself to modern tenure and been devoted to the homely function of bringing in water and clearing out the sewage of that ancient, not to say archaic burgh, even if in the process individual had taken the place of communal right.

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[*] See *Antiquary*, vol. iv. p. 101.

[†] See Burt's *Letters*, vol. ii. p. 34 *et seq.*, for condition of agriculture even in the last century.

[‡] Cosmo Innes, *Scot. Legal Antiquities*, p. 263.

It is seven centuries since these ancient systems we have been considering have exercised any direct or practical control over the tenure of the land in which we live, seven centuries full of change and of incident, powerful enough even if compressed into a briefer period to have severed any connection which the active life of the present day could have had with the defunct systems of an almost prehistoric age. But while no doubt much pedantry and affectation have been of late exhibited in the attempt to ascribe to these archaic systems an influence on our modern institutions which it is impossible for the real student to recognise or admit, still we must bear in mind that those feelings and sentiments which affect the relation of man to his mother earth are deep enough to permit the roots of society to sink into them far below the stage on which the prominent drama of history is enacted; that relation underlies the very framework of society itself, and systems which have regulated the relation of man to the earth which bears him and feeds him continue to exercise a powerful influence over his imagination and feelings long after they have ceased to operate on the actual circumstances of his outward life. Nor from the analogy of other sciences need we be surprised if this recent stirring of these substrata of our early society gives birth to strange efforts to revert to ancient types; these efforts are no doubt due rather to individual eccentricity than to general conviction, just as in nature we find occasional specimens of highly developed species which exhibit a sportive inclination to revert to primeval types from which lengthened cultivation has really far removed the whole class to which they belong.

There are, however, not a few side lights which the fitful gleams we get in studying these ancient types of society may throw into the origin and pristine circumstances of those relations which subsist in our own day. For instance, the theory of rent most acceptable to modern economy and most consonant with modern circumstances is that which represents the rent as the share falling to the landowner of the profits of a quasi-partnership, to the capital of which the owner contributes his land and the tenant his stock, his labour, and his skill. Very ancient types of society justify this theory, and in many parts of Europe more subject to Latin influences than we have been it survives in the metayer systems which prevail; but it is on the whole a modern development, and bears abundant evidence of its origin in a state of society much more cultivated than any of those we have been considering. The rent of our ancient tenures was originally in the main personal service, and even when it began to assume the form of money payment it was a pecuniary substitution for such services or for that direct maintenance in bed and board which the king or the chief exacted; and it was always fixed and definite, bearing no necessary relation to the *value* of the land. The foundation of our ancient relation between landlord and tenant was not, I apprehend, partnership but sale; a tenant did not share the produce with his landlord, he bought the temporary use of his farm for a certain price payable by instalments during the lease; he was more a temporary feuar, or a copy holder, than a tenant in our sense of the term. And herein lies a very important and curious distinction between ancient and modern economy, which is the key to many difficulties; with us, the price of an article and its value are almost convertible terms, but it was not so of old, it was not so not very long ago. Price was *fixed* in the ancient times I speak of by custom, and when we read with wonder of statesmen in even modern times seeking to fix the price of viands by enactment they were only struggling with the idea which in pristine societies fixed *price* by inveterate custom. Even now in India there are districts where the price of shoes for instance is fixed by inviolate custom, and the shoemakers adapt themselves to circumstances not by altering the price but by modifying the quality of their goods; and not very long ago in some European countries the price of the loaf was fixed and its dimensions fluctuated.

Now in England we know that the rent of the land has not even yet borne the same intimate relation to its value it has done in Scotland; the rent which a man's father and grandfather paid before him has lingered there as an almost customary rent different in degree rather than in principle from the really customary rent of the copyhold tenure; and the commercial principle which our modern practice especially in Scotland has introduced of close identity between value and price has in England penetrated with the slowness proverbial to agriculture into the relations bearing on land. I think there may be some of the unsolved problems of this relation upon which the consideration of what I have thus referred to may throw a little light.

Another ancient fact bearing on the landlord and tenant of our modern experience seems worthy of some note; the pristine form of that relation was, as I have already shown, of an alternative character. The tenancy might be one practically of steelbow, in which the landlord supplied stock, implements, and the scanty housing if any; or it might be that by which the landlord sold temporarily the use of his land only, leaving the tenant to supply himself with all that he required for its cultivation. It was this latter form mainly that survived into later times. We have of course no written leases remaining to us of the very early times to which I have been specially referring; but those early leases which do remain entered into at a date when owing to the inveterate habits of a rural people, the main features of the early contract must have survived, the stipulation that the tenant should supply the houses, &c., required for the proper cultivation of the farm is to be found. In a lease, for instance, so early as 1312* it was stipulated that the tenant should supply suitable buildings for himself and his husbandmen, which were to be left at the end of the lease; after an interval of two centuries, under the next earliest lease of which I have seen any note, in 1511 the tenant is taken bound to build three onsteads to be inhabited by himself and his dependants under pain of forfeiture; a crofter is taken bound to build a rood of enclosure for every cow he has on the lands of the principal tenant; and in two cases tenants were taken bound to build houses on their farms, but were allowed to retain a part of their rents to assist them in doing so. These were church lands, and we may be sure these stipulations represent nothing more severe than the usual tenure, but probably the reverse. Now such a system was quite consistent with the idea of a partial or temporary sale of the subject, which was the bare land, not as in steelbow the land equipped with stock and appliances of which the wattled houses of these early days formed probably no very important part; but it was quite inconsistent with the more developed ideas of modern economy basing the lease on quasi-partnership, and was not suited for our modern use with the more important outlays now required for modern agriculture. It is well, however, to discern from these examples that the principle now universally recognised as the best, which imposes on the modern landlord the necessity of supplying all that is required for the full equipment and beneficial cultivation of the farm, or of recouping to the tenant what he may dispense for such purposes, is no exhumation, as has been often represented, of ancient custom or tenure —no reverting to a more generous system long forgotten. Antiquity knew nothing of the kind, or if the steelbow form of lease is to be taken as the archaic type of what is advocated, then the experience of seven centuries and the advance in independence of the agricultural class have demonstrated that that system is unsuitable, for it has failed to survive. It may be less interesting but it is certainly safer, instead of searching for principles and precedents for our present guidance among the archaic systems of the past, to recognise that even the highest forms of these were datum lines from which to

* Innes, *Legal Antiquities*, pp. 263, 264.

measure our own advance. The history of land tenure is the history of progressive emancipation; to represent the changes necessary to adapt it to our advance in economic science and social development as a process of reverting to the spirit of ancient practice is to subvert the teaching of history; it is to the progress, not the retrogression of ideas on this as on other topics that we have to ascribe the advance we have made and are making; it is what is most fit for our modern life that survives, not what may be most interesting or picturesque.

No section of the inquiry into the relation of man to the soil is so difficult of solution as that which relates to the poor, and none to us of the present day is more interesting. If, as seems to be thought by many, there were days in this land in which the poor were not always with us, no wonder longing glances are thrown backward to catch even amidst the darkness of barbarism glimpses of so happy a condition. But a closer study of the facts dispels the illusion; besides the abnormal growth of population to which the Duke of Argyll referred in a recent essay (which is, in my humble opinion, the ablest contribution yet made to the economical treatment of this subject)* there are other elements—two especially—which do not appear to me to have received adequate consideration; if the days to which we have been referring were ignorant of poverty, it was greatly due to these facts, that slavery held its place in their economy, and that the habits of all classes of the people rendered them to a large extent independent of external supply—they were largely self-sufficing.

The nature of the slavery of these remote times it is very difficult accurately to distinguish; it was certainly of at least two distinct forms. There were the serfs, the *nativi*, probably the descendants of an ancient race, often the members of tribes which had been subjugated by stronger neighbours, always attached to the land, and not apparently removable from it even with their assent, and almost certainly not without it. These serfs were slaves in this respect that they had neither in the Celtic nor in the Saxon economy any rights; but if the land held so tight a grip on them, they in turn held a tight grip on the land, and had certainly claims on their lord or owner, though whether these claims were those of an inherent right to support or proceeded merely from the self interest of the lord himself in the preservation of his property, it is very difficult to say.

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* See *Contemporary Review*, January 1883.

But below these there was a class of slaves who were mere personal property; probably orignally captives of war, but latterly in many instances freemen who had been reduced to want, and who sold themselves as a condition of receiving maintenance and prosection from the powerful and rich; and this sale affected their posterity.

While there seems very little doubt that the position of the predial serfs even if originally equivalent to that of slavery became latterly a mere form of tenure of service, and that they had probably to endure none of the degradation of positive slavery, there can be no doubt that it was not so with the other class. Theirs was a slavery from which men fled in horror, and to which they were dragged back in terror and in chains. The early Acts of Parliament abound with evidence of this and with directions for the recovery of fugitives, and even in the 14th century slaves were recaptured, and handed back to their owners under sanction of the law.

These were the poor of the ancient tenures, and we can readily discern why they were so largely dependent on the lords of the soil for maintenance and defence; their gradual emancipation from actual serfdom or slavery followed insensibly on the development of the church and the progress of society, but their dependence on the chief or lord continued, and while they swelled the train of his followers they looked to him for support. This was a burden which speedily began to press on the chiefs in the Highlands, and although plague, pestilence, and famine came largely to their relief, the growth of the population impelled them insensibly into that turbulence and restlessness which distinguish the annals of our Highland life; it is not perhaps so picturesque as one would wish to ascribe the frequency and the fierceness of Celtic feuds to the mean necessities of the larder, but these economic forces were too powerful to be ignored in any veritable history of the clans.

It is very interesting to those who study these ancient forms of life to find extant, or only recently extinct, forms of society possessing all the main features which we have reason to believe characterised these early days in our own country. The practical experience of men like Sir H. Maine and Sir George Campbell and other scholars who have applied their knowledge of the Aryan races in India to the elucidation of our Scotch archaic history has thrown much light on the subject; but I think a speech made a few weeks ago by Dr Hunter in the council of the viceroy on the treatment of the people of the Deccan is singularly illustrative of the subject I am now treating. "The peasantry of the Deccan," he said, "have been suffering from economic causes sufficient to break the spirits and to ruin the fortunes of any race. Seventy-four years ago, when the Mahrattas and the peasantry of the Deccan passed under our Government, they had five great sources of livelihood. The economic and political changes brought about by British rule have deprived them of four of these sources and left them only one. In the first place, the Mahratta race had, during nearly two centuries, derived a large, although a fluctuating, income from war. Its pillaging invasions of wealthier provinces were reduced to a system of strictly mercantile adventure, which enriched alike the fort of the chief and the cottage of the peasant. For the Deccan hordes were not the accidental product of any single leader, but the natural result of an overflowing peasant population under the guidance of a hereditary administrative caste." I thought I had read this before, and turning to Cosmo Innes's charming essays on our early Scotch life, I found this :—"The power of the chief or *laird* was measured by the number of men he could turn out under arms, and he had every inducement to maintain the full number of dwellings and inhabitants. In summer the people of the glen might exist upon the produce of their pasture lands, and there was a little corn for the beginning of winter, but for the rest of the year they must necessarily have sought sustenance elsewhere. They could not dig, to beg they were ashamed. There was a third alternative, they left their glens and *lifted*."*

Dr Hunter goes on to show how the advance of civilisation has dried up the sources of the former wealth and even subsistence of the Deccan peasantry, and we could tell the same story of our own land; the looms of Galashiels and Hawick have silenced those in the Highland glens, and all the manifold changes that railways and steamers have introduced into the habits of a people formerly so self-contained and self-sufficing have conduced to the reduction of

* Innes, *Scottish Legal Antiquities*, p. 269.

the value of such labour as the Highlands supplied. Lassalle and Karl Marx in their crusade against modern plutocracy have depicted with great force and skill the vast difference which there is between a system of society which is content to supply only its own necessities from day to day and that high pressure of modern life, which, stimulated by capital ever eager and hungry for gain, manufactures on speculation, and anticipates demand by an ever-ready and often over-abundant supply. Lassalle, speaking of the feudal lord of Germany, says:—"Look upon the landed proprietor during the middle ages, the noble lord surrounded by his castles, his manors, his vassals, serfs, and dependants, his allodial villages and tributary towns. Was this man a capitalist? Let no one suppose that people lived on the produce of the land only, which is the crude notion of some people. Production was sufficiently developed, luxury considerable, and the articles of consumption manifold and refined." He then proceeds to give from mediæval writings a description of prevailing fashions in wearing apparel, furniture, and the like, showing the advanced state of fashionable society then and its varied requirements. He shows how all these are provided by the combined contribution of vassalage, by what he calls a "mosaic work of services." Under this system man is no longer a slave, but his will is the private property of another. There is an exchange of services and natural products without the intervention of money as a general measure of value. "The acres of the feudal lord" he points out "are cultivated not only by serfs but with the help of man and beast, by means of villenage more or less reasonable in extent, varying from three days in the week to five or six weeks in the year, according to the position of the feudal dependant." Then again, he says, "put yourself in imagination back to one of the days for collecting the yearly revenue, when the feudal lord receives his dues. Then you will see heaps of corn and barley, chicken and bacon, oxen and swine, eggs and butter, oil, fruits, wax, candles, honey, yea even cakes, bouquets, and *chapeaux de rose*, all contributed by his faithful lieges. The tailors and shoemakers of the small town under his protectorate, remembering the principle *nulle terre sans seigneur*, bring their clothes and shoes which have been made during the week's service they owe him." Similarly he enumerates the various tradesmen and artisans who are bound to contribute their respective portion of the lord's requirements in natural or manufactured goods; and a long inventory of services rendered to his household by their wives and others belonging to them follows, all to show "that scarcely a want can be conceived which is not provided for by some special obligation in this system of natural services. Even professional men like advocates must give their advice as a duty, free of charge, to the lord of the manor. His amusements even are provided for him by his own dependants free of charge. He is a wealthy man, without the possession of money; for he cannot turn these services or commodities into capital. He avails himself with a vengeance of all these means of enjoyment which are thrown with such profusion around him, and he does it cheerfully without care or worry, and thus is more happy than the rich speculator of modern days whose tranquil enjoyment may be disturbed by a passing thought about the money market as he listens to the music of Beethoven or Mozart. But beyond consuming with enjoyment the feudal lord has nothing. He has no means to multiply his wealth by itself; not money but service was the common bond uniting all the members of the empire among themselves and under a common head.

"By this system of fixed services and mutual obligations no room is left for capitalistic enterprise or industrial progress, the whole process of production receives a stereotyped form, agriculture and the trades run on without change in the same groove." *

The Highland chief of old lived very much as, Lassalle so picturesquely points out, the old feudal lords lived, if upon their people, yet with them and among them; they supplied all his wants, and these supplies and their personal services fulfilled all their obligations. The people had no money, and they needed none; they paid their rent in kind or by service, their necessities were few, and their commerce had not risen above the rudimentary stage of exchange; the chief had no money wherewith to import foreign commodities, and he lived in the rude plenty which his people supplied; when his supplies failed we know how they were replenished. All these influences have told on the poorer class in the Highlands especially, and it is interesting and may be useful to inquire how modern economy has coped with the difficulties presented to it by the extinction of ancient habits and resources.

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* *Socialism.* Henry S. King & Co., 1874, p. 73.

To translate the serf and the slave of ancient life into modern language, I would use the word "dependant"; that I think conveys more of the spirit of the ancient relation with its mutual service and protection than the terms of slave and serf, which convey a harsher meaning than probably describes the true nature of the tie which bound the earliest predecessors of the chiefs to those below them. Now, in our modern life, how has this relation adapted itself to modern systems? The chief, though deprived of the services of his dependants, has been forced to maintain and protect them; not in the grand patriarchal manner of ancient times, and with none of their pomp and panoply of war, and with none of their keen zest for raids and marauds; he has to pay poor rates. But translated into the vernacular of our modern life he has no light burden thus to defray. I have taken ten parishes in Inverness, and eight in Ross, of which the gross rental in the one case is £58,000, in the other £64,000; of the £58,000 in Inverness, £15,800 is paid by tenants under £10; of the £64,000 in Ross, £17,500 is paid by tenants of the same class. The poor rates paid in the ten Inverness parishes amount to £6200, in the eight Ross parishes to £8300. I cannot state accurately the school rate, but one of the inspectors in his last report says it varies in one of these districts from 2s. to 6s. 8d. per £. I have taken it at the lowest amount, and we have thus in the Inverness group an assessment of £12,000, and a rental under £10 of £15,800; in the Ross-shire group an assessment of £14,700 a rental under £10 of £17,500. Now I cannot here attempt to determine what precise proportion of that assessment is due to the special necessities of the small tenants under £10, but everyone will admit it must be very large. For the maintenance and education of the poor in these districts the land has to pay annually about 90 per cent. of the nominal rental under £10, and a proportion of course very much greater of the real rental actually drawn. It is safe to say that more than the whole rental under £10 is required to defray the expense of maintaining and educating the poor. It can hardly therefore be said that the survival of the relation between the land and the poor from ancient times, if it has been in many respects painful to those who were the dependants of the old chiefs, has been favourable to the successors of the chiefs themselves—the fathers no doubt ate sour grapes in the olden time, and the teeth of the children have been set very much on edge by the operation.

But the landlords are not the only survivals of those on whom the poor of the ancient times were dependent; as stated by Mr Innes, and as illustrated by many a stirring tale of old, others besides the landlords were made to contribute to the necessities of the noble peasantry of the glens. When in 1856 and in other years, as now, the successors of the douce provosts of olden times invite us to contribute to relieve the urgent necessities of the suffering Highland poor, they are only putting into modern language the levy their predecessors would have made upon us to pay the black mail the clans would have exacted when their domestic means of subsistence failed, as they have done. At no time within modern history, since population began to grow beyond very narrow limits, have several of the poorer districts of the Highlands been able to supply their own needs; there has never been a time when the plenty of one period has there sufficed to meet the scarcity of another; whether the levy has been by war, or by tax, or by charity, extraneous aid has always had to contribute its quota. As the Duke of Argyll has recently reminded us, nature in old times, when population outgrew its bounds, asserted her inexorable laws by sending plague, pestilence, and famine to clear off the surplus; our modern civilisation has curbed these powers, as well as repressed the social characteristics which accompanied and assisted them, and thus is presented to us the same problem, though within far narrower limits, which is pressing on the Government of India—the growth of a population at a rate far in excess of that in ancient times, bringing on our modern economy and social science burdens due to their own beneficence.

The suggestion so frequently made of late that the poorer cottars and crofters of the Highlands are the inheritors of ancient tribal rights in the land is, as I have already shown, quite fallacious; the relation of dependence in which that class unquestionably stood not only in feudal times to the later lords and chiefs, but in still earlier days to the original freeholders of the tribal organisation, did not permit of their having any rights; the exclusive system of the tribe, the restriction of all rights to the freemen, forbid the possibility of any rights in the land having been held by those who were below that rank; and there can be no doubt that the freemen of the tribe grew into the chiefs and the lairds, the feuars and kindly tenants of later days, of whom the cottars and crofters are in no sense representatives. Here, again, I would point out how dangerous it is to refer to analogies in those early days without due care in establishing their identity with the modern circumstances they are intended to illustrate. It is a safer course to let these dead systems bury their dead—and to apply ourselves to the careful study of our own social problems by the brighter light of our own social progress. In that light it humbly appears to me that the frequent recurrence of Highland distress is a reproach on our modern economy from which ancient systems were free, however that freedom was obtained. It is foreign to the subject of which I treat to pursue this subject, but this I may say, that dealing with people who have been for ages habituated to be led, to be dependent for guidance on others, to be protected by others, who are only emancipated but not yet free, if our modern system is to fulfil the duties it has inherited from the past, it must supply that initiation and guidance and motive power and influence which of old, under very different circumstances and in very different directions, the chiefs of these people supplied: to parody a well-known aphorism, relief is no cure: it is the proper task of modern economy to show these people the method, to induce them to adopt the measures, and even to supply them with the means to win that independence which is a nobler, and will be a more useful inheritance than any that they claim from the distant past.

I had intended to say something as to the taxation on the land of these ancient days and its relation to our modern imposts, but I have already far exceeded the limits of my paper and must conclude. I have fulfilled my purpose if I have directed attention to, and created any interest in, the salient features of those ancient tenures which are in any way reflected in our present social system; and if I have succeeded in demonstrating that after all it is more as studies and as cabinet specimens than as models that we must regard them; that they were only the nurseries of society, not even its schools; interesting and picturesque no doubt, attractive but deceptive, festooned with the mosses and encrusted with the lichens that adorn the decay while they conceal the defects of hoar antiquity.

Table showing Rental, Poor Rates, and School Rates of certain Highland Parishes, 1881–82.

PARISH.	Gross Rental.	Rents under £25.				Over £25.	Poor and School Rates on Gross Rental.		
		£25–10.	£10–4.	£4–0.	Total.		Poor Rates assessed.	School Rates assumed at 2s.	To-gether.
	1	2	3	4	5	6	7	8	9
1. Portree, . . £	8,314	1,697	1,454	467	3,618	4,593	1,039	831	1,870
2. Kilmuir, . .	6,119	1,071	1,195	48	2,314	3,736	484	611	1,095
3. Snizort, . .	5,802	674	1,162	202	2,038	3,715	628	580	1,208
4. Diurinish, .	7,702	531	1,697	678	2,906	4,646	481	770	1,251
5. Strath, . .	5,308	366	739	492	1,597	3,587	552	530	1,082
6. Sleat, . . .	4,440	233	440	542	1,212	3,099	481	440	921
7. Barra, . . .	2,217	167	186	483	836	1,345	369	221	590
8. S. Uist, . .	6,680	609	1,874	1,084	3,567	3,018	807	668	1,475
9. N. Uist, . .	5,443	458	1,281	381	2,120	3,152	681	544	1,225
10. Harris, . .	6,141	370	1,014	359	1,743	4,278	665	614	1,279
£	58,166	6,176	11,042	4,736	21,954	35,169	6,187	5,809	11,996
1. Barvas, . . £	3,212	203	678	1,581	2,462	668	535	321	855
2. Lochs, . .	4,671	69	420	1,686	2,175	2,423	855	467	1,322
3. Stornoway, .	14,139	3,106	2,542	2,475	8,123	4,556	2,002	1,413	3,415
4. Uig, . . .	5,229	92	706	732	1,530	3,656	620	522	1,142
5. Lochbroom, .	15,089	498	1,465	1,007	2,970	12,085	2,011	1,508	3,519
6. Gairloch, . .	11,588	493	930	1,096	2,519	9,005	1,158	1,158	2,316
7. Lochcarron, .	5,758	833	574	278	1,685	4,052	359	575	934
8. Applecross, .	4,401	299	619	698	1,616	2,732	751	440	1,191
£	64,087	5,593	7,934	9,553	23,080	39,177	8,291	6,404	14,695

The sum under column 1 includes in addition to Nos. 5 and 6, the rental of land held by school boards, &c.

2. On the Microscopical Appearances of Striped Muscular Fibre during Relaxation and Contraction. By Professor Rutherford.

BUSINESS.

In terms of the Laws, a ballot took place for the following proposed Honorary Fellows:—*As Foreign Honorary Fellows*—Luigi Cremona, Rome; Julius Hann, Vienna; Charles Adolphe Wurtz, Paris. *As British Honorary Fellows*—Sir Joseph Dalton Hooker, Kew; Dr Spottiswoode, London; Professor Williamson, London; Col. Henry Yule—who were all declared duly elected as Honorary Fellows.